A TECHNICAL AND ECONOMIC ANALYSIS OF SOLAR ENERGY PROJECTS AT FORT HUACHUCA, AZ

Prepared by the

Sandia National Laboratories

Solar Thermal Design Assistance Center

February 11, 199~~7~~4

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS
P.O. BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005

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FORT HUACHUCA

RELOCATION OF FIRE HOUSE SOLAR SYSTEM

Sandia's Solar Thermal Design Assistance Center was asked to evaluate the advantages of relocating an existing solar system to another location. The existing system consists of two flat plate collectors, a 60-gallon storage tank, a Grumman heat exchanger and differential temperature controller, and circulation pumps. Reports indicated that the controller was no longer functioning. The system is installed on an old fire house; however, occupancy of the firehouse is changing, and there is no longer a load for the solar system. We looked at several sites and decided to study relocation of the system to the JITC building.

The JITC building has 24-hour occupancy and a high hot water load due to its having both showers and a kitchen. The equipment room is located on the second floor and has easy access to the flat part of the roof. In addition, there is ample space in the equipment room for the storage tank, heat exchanger and controller.

We estimate it to cost \$800 dollars to move the system, plus \$100 to buy a new differential temperature controller. We used an INSOL computer program and a spreadsheet to compute an displaced natural gas savings of 32 MMBTU each year, for a yearly cost savings of \$195. This project has a savings-to-investment ratio (SIR) of 3.1 and a simple payback of less than 5 years. In addition, pollution reduction of CO_2 would be 12,189 pounds per year and 43 pounds of NO_x each year.

John Henrie of the JITC building suggested that he may have base personnel who can move and install the system. If base personnel do install the solar system, I suggest that a solar system supplier/installer be hired to fill, check out and start up the system.

ECIP DOCUMENTATION

FOR THE RELOCATION

OF THE FIREHOUSE SOLAR SYSTEM

01!Fort Huachuca
P1BILL STEIN
P2DSN 821-1861
P3ATZS-EHE
/RECALL F 000042372 S 03
03A !DESCRIPTION OF PROPOSED CONSTRUCTION
Remove a solar collector system from the old Fire House and install the system on the JITC Building 57305). The solar system will augment the existing domestic hot water heater that supplies hot water to the showers, faucets and kitchen. The solar system system consist of two collector panels, heat exchanger, pumps, controls and a 60 gallon storage tank. This project has an SIR of 3.06 and a simple payback of 4.6 years.

***
03B !REMARKS
The energy generated by the solar system will displace 32MMBTU's per year of natural gas. Annual cost savings are calculated by the current price of natural gas times the solar BTUs delivered divided by the water heater efficiency. It is recommeded not to install a BTU monitoring system as the cost of the monitoring system will exceed the cost of this project.

***
03C !PROJECT DESCRIPTION
The solar array will be installed on the roof of Building 57305 and the balance of the equipment will be installed in the west mechanical equipment room located on the second floor.

***
03D !REQUIREMENT (Why is it needed now)
The project is required to help Fort Huachuca meet the energy reduction goals and renewable energy usage goals in a life cycle cost effective manner. This project will reduce operating cost by $195 per year and reduce annual pollution of CO_2 by 12,189 pounds per year and NOx by 43 pounds per year.

***
03E !CURRENT SITUATION (How is the need currently being met)
The existing system consist of a gas fired domestic water heater.

```
***
03F  !IMPACT IF NOT PROVIDED
Energy reduction targets will not be met.  Renewable energy
usage targets will not be met.  The operating budget will
not decrease.  There will be no decrease in air pollutants.
The Fire House solar system will continue to not be used as
there is no hot water load in the old Fire House.


***
03G  !ADDITIONAL
***
03I  !RELATED PROJECTS


***
/*
/RECALL F 000042372 S    07
07A  !GENERAL JUSTIFICATION DATA
The justification data for this project can be found in this
report and the attached LCCID computer printout.  All
analysis was performed by the Sandia National Laboratories
(SNL) Solar Thermal Design Assistance Center (STDAC).  The
cost of the energy is the cost to the building as of 1 Jan
94 of $6.13 per MMBTU per the Fort Huachuca Base Energy
Coordinator.

***
07B  !TRAFFIC ANALYSIS
This project will have no impact on traffic.


***
/*
/RECALL F 000042372 S    08
08B  !PRESENT ACCOMODATIONS AND DISPOSITION
There are no disposal actions for this project.


***
/*
/RECALL F 000042372 S    09
09D  !RPMA DISCUSSION
This project will decrease the utility bill by $195 per year
with no increase in the maintenance budget.


***
/*
/RECALL F 000042372 S    10
10A  !ANALYSIS OF DEFICIENCIES
Fort Huachuca has some of the best Solar Insolation in the
United States and also has one of the highest industrial
natural gas rates in the nation.
```

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***
/*
/RECALL F 000042372 S     11
11D  !DECISION ANALYSIS
The question was asked if it would be cost effective to
relocate the old Fire House solar system.  The solar
relocation option was explored by the STDAC from SNL with
funding provided by The Department of the Army, Corps of
Engineers.

***
11E  !ECONOMIC ANALYSIS
See attached LCCID computer printout


***
/*
/RECALL F 000042372 S     12
12A  !CRITERIA FOR PROPOSED CONSTRUCTION
It is recommended that this be a design build project based
on the study done by SNL.  This project should use existing
solar equipment and off the shelf components as required.


***
12B  !USER DISCRETIONARY BLOCK
This would be an excellent project using existing solar
equipment.  This project also highlights the mutual support
between the Department of the Army and the Department of
Energy.  The payback period is 4.6 years and the SIR is
3.06.


***
/*
/RECALL F 000042372 S     15
15A  !ENVIRONMENTAL DOCUMENTATION


***
15B1 !SUMMARY OF ENVIRONMENTAL CONSEQUENCES
Reduction of air emissions.


***
/*
/RECALL F 000042372 S     19
19A  !SUMMARY OF ENERGY REQUIREMENTS
This project will reduce the use of natural gas by 32 MMBTU
per year.
```

***
19B !SUMMARY OF UTILITY SUPPORT
Electricity to run the controls and two fractional horsepower pumps is available in the equipment room of Building 57305.

***
19C !USER DISCRETIONARY BLOCK
This project will be a success if the recommendation to do a design build contract is followed.

***
/*
/RECALL F 000042372 S 21
21A !CA ANALYSIS CONCLUSIONS
This was not done due to the lack of funding and manpower at the installation level.

***
21B !EXECUTIVE SUMMARY OF CA ANALYSIS
N/A

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: FIREHOUS
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.080
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0003 FIREHOUSE R&R
FISCAL YEAR 1994 DISCRETE PORTION NAME: R&R
ANALYSIS DATE: 02-11-94 ECONOMIC LIFE 15 YEARS PREPARED BY: JRA

1. INVESTMENT

A. CONSTRUCTION COST	$ 900.	
B. SIOH	$ 0.	
C. DESIGN COST	$ 0.	
D. TOTAL COST (1A+1B+1C)	$ 900.	
E. SALVAGE VALUE OF EXISTING EQUIPMENT	$ 0.	
F. PUBLIC UTILITY COMPANY REBATE	$ 0.	
G. TOTAL INVESTMENT (1D - 1E - 1F)		$ 900.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.70	$ 0.
B. DIST	$ .00	0.	$ 0.	13.78	$ 0.
C. RESID	$ .00	0.	$ 0.	16.02	$ 0.
D. NAT G	$ 6.13	32.	$ 195.	14.16	$ 2754.
E. COAL	$ .00	0.	$ 0.	11.57	$ 0.
F. PPG	$ .00	0.	$ 0.	11.12	$ 0.
M. DEMAND SAVINGS			$ 0.	11.12	$ 0.
N. TOTAL		32.	$ 195.		$ 2754.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.12
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
d. TOTAL	$ 0.			0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3Bd1/(YRS ECONOMIC LIFE)) $ 195.

5. SIMPLE PAYBACK PERIOD (1G/4) 4.63 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 2754.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(6 / 1G)= 3.06
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 12.05 %

ECONOMIC & PERFORMANCE ANALYSIS

FOR THE RELOCATION

OF THE FIREHOUSE SOLAR SYSTEM

FORT HUACHUCA FIRE HOUSE SOLAR SYSTEM				
Collector Square feet =	64			
Solar System Efficiency =	0.45			
Boiler Efficiency =	0.70			
Gas Price ($/MMBTU) =	6.13			
	Solar	Solar	Displaced	
Month	Available	Delivered	Nat. Gas	Savings
	btu/sf/mth	Btu/mth	btu/mth	$/mth
January	51100	1.47E+06	2.10E+06	13
February	54700	1.58E+06	2.25E+06	14
March	68700	1.98E+06	2.83E+06	17
April	75400	2.17E+06	3.10E+06	19
May	78100	2.25E+06	3.21E+06	20
June	72700	2.09E+06	2.99E+06	18
July	66100	1.90E+06	2.72E+06	17
August	68100	1.96E+06	2.80E+06	17
September	66100	1.90E+06	2.72E+06	17
October	66800	1.92E+06	2.75E+06	17
November	54300	1.56E+06	2.23E+06	14
December	49200	1.42E+06	2.02E+06	12
TOTAL			**31,733,486**	**195**

	FIRE HOUSE SOLAR SYSTEM RELOCATION		
	COST ESTIMATE		
Flush heat exchanger =		40	
New Controller =		100	
R&R solar sytem, labor =		584	
Copper piping & fittings =		176	
	TOTAL =	900	
Natural gas savings /yr =		32	MMBTU
Natural gas $/MMBTU =		6.13	
TOTAL SAVINGS =		$196	/year
Assume 15 year life as this is a used system, but in good condition			

INFORMATION PREVIOUSLY SENT TO

MR. JOHN HENRIE REGARDING

THE RELOCATION

OF THE FIREHOUSE SOLAR SYSTEM

Sandia National Laboratories

Albuquerque, New Mexico 87185-0703

November 19, 1993

JITC Building 57305
Attn: Mr. John Henrie
TCCBA 7020
Fort Huachuca AZ 85613

Dear Mr. Henrie:

This letter is in regard to the proposed project to move the Old Fire House solar system to the JITC building. This effort is in support of the U.S. Army Corps of Engineers.

The existing solar system consists of two flat plate solar collectors, a heat exchanger, a 60 gallon storage tank, circulation pumps, and a differential controller. The equipment appears to be in good condition, however, it is reported that the differential controller may be bad.

I estimate the cost to remove the system from the firehouse and relocate to the JITC building to be approximately $800, including a flush of the heat exchanger. A new Gruman differential temperature controller will cost an additional $100. Total expected costs are $900.

If fully utilized, this solar system will generate and deliver approximately 22.5 MMBTU per year of energy. At a cost of $5 per MMBTU for natural gas (per Bill Stein) and a boiler efficiency of 70%, a savings of $160 per year can be realized.

You may have two methods for relocating the solar system to the JITC building:

> Method one is to use base personnel to move and install the system. I suggest you then hire a solar contractor to fill the system with a water/glycol mix and place it into operation. This contractor should be responsible for any repair work such as replacing the differential controller, if necessary.
>
> Method two consist of hiring a solar contractor to move and install the solar system, including making the system operational.

The solar collectors can be mounted on the flat part of the roof facing south and at a tilt of 30 degrees. The storage tank should be placed in close proximity to the existing domestic water heater such that it does not create access difficulties to existing equipment. All piping should be insulated. The solar loop should be filled with a 30% propylene glycol solution to prevent freeze damage to the collectors and associated piping.

Solar Thermal Technology Department 6216, MS 0703 Phone: 505-844-0800, Fax: 505-844-7786

I have contacted the Arizona Solar Industries Association and they have suggested that the following local (Tucson) licensed contractors would be capable of performing the required work:

1. Desert Solar Design
2. Sunpower

For your information, I have attached a sketch of the proposed system and a LCCID analysis assuming a contractor moves and installs the system. Please do not hesitate to call me if you have any questions or require additional information.

Sincerely,

John Anderson, 6216,
Solar Thermal Technology

Copy to: w/attachments
Ft. Huachuca Bill Stein
6216 J. R. Anderson

Copy to: w/o attachments
COE Nat. Hunter
DOE/AL N. Lackey
6201 P. C. Klimas
6215 C. P. Cameron
6215 E. E. Rush
6216 C. E. Tyner
6216 D. F. Menicucci

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: FIREHOUS
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.072
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0003 FIREHOUSE R&R
FISCAL YEAR 1994 DISCRETE PORTION NAME: R&R
ANALYSIS DATE: 11-12-93 ECONOMIC LIFE 15 YEARS PREPARED BY: JRA

1. INVESTMENT

A. CONSTRUCTION COST	$ 900.		
B. SIOH	$ 0.		
C. DESIGN COST	$ 0.		
D. TOTAL COST (1A+1B+1C)	$ 900.		
E. SALVAGE VALUE OF EXISTING EQUIPMENT		$ 0.	
F. PUBLIC UTILITY COMPANY REBATE		$ 0.	
G. TOTAL INVESTMENT (1D - 1E - 1F)			$ 900.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.70	$ 0.
B. DIST	$ .00	0.	$ 0.	13.78	$ 0.
C. RESID	$ .00	0.	$ 0.	16.02	$ 0.
D. NAT G	$ 5.00	32.	$ 161.	14.16	$ 2273.
E. COAL	$ .00	0.	$ 0.	11.57	$ 0.
F. PPG	$ .00	0.	$ 0.	11.12	$ 0.
M. DEMAND SAVINGS			$ 0.	11.12	$ 0.
N. TOTAL		32.	$ 161.		$ 2273.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.12
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
d. TOTAL	$ 0.			0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

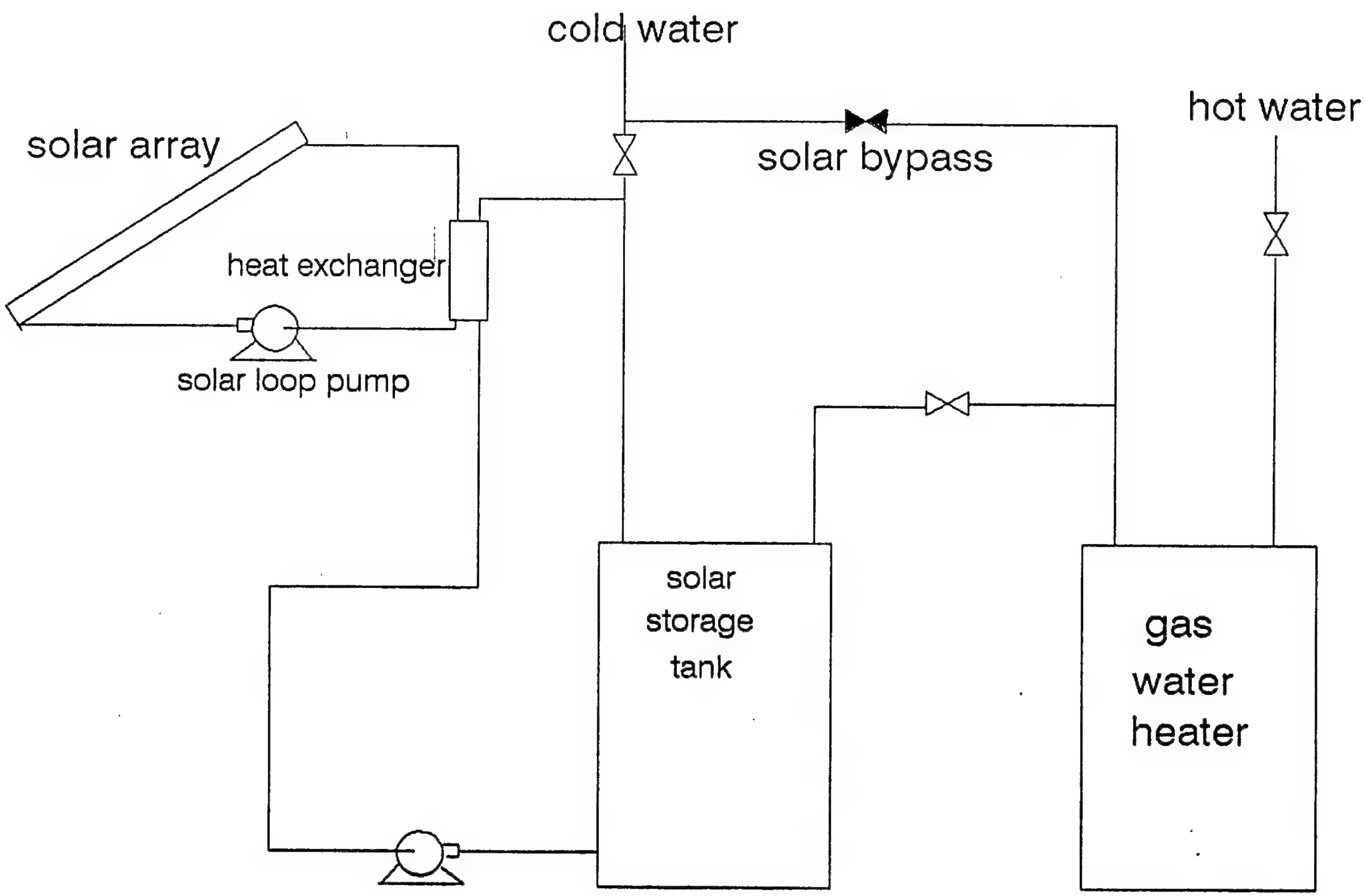
4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3B1d/(YRS ECONOMIC LIFE)) $ 161.

5. SIMPLE PAYBACK PERIOD (1G/4) 5.61 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 2273.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(5 / 1G)= 2.53
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 10.62 %


cold water
hot water
solar array
solar bypass
heat exchanger
solar loop pump
solar storage tank
gas water heater

FORT HUACHUCA

SOLAR POOL HEATING

Sanida's Solar Thermal Design Assistance Center (STDAC) was asked to analyze the cost savings of each pool heating collector panel at the Barnes Field House. The existing system is a drainback system with 54 unglazed copper panels. One sixth (9 panels) of the collector field is out of service due to wind damage.

Data provided to the STDAC showed that during the first year of operating the entire solar field the natural gas savings was 834,874 cubic feet. This is a 15.6 MMBTU and \$96 per year savings per panel. Copper panels can be purchased and installed for \$358 each. This results in a savings-to-investment ratio of 4.7 and a payback of less than 4 years. Each solar collector panel reduces pollution by 5,942 pounds of CO_2 and 21 pounds of NO_x each year.

Polypropylene unglazed panels can be purchased and installed for \$240. Polypropylene panels are suitable for pool heating and have the advantage or not being sensitive to pH as are the copper panels.

MMBTU = 15.6 x 54 = 842.4
\$ = 96 x 54 = 5,184

ECIP DOCUMENTATION

FOR THE

POOL HEATING SOLAR SYSTEM

01!Fort Huachuca
P1BILL STEIN
P2DSN 821-1861
P3ATZS-EHE
/RECALL F 000042372 S 03
03A !DESCRIPTION OF PROPOSED CONSTRUCTION
Replace solar collectors that have suffered wind damage. The existing solar system is used to heat the pool located at the Barnes Field House. Empirical data shows that each collector panel displaces 15.6 MMBTU per year of natural gas. This project has an SIR of 4.7 and a payback of 3.95 years.

***
03B !REMARKS
The energy generated by each collector of the solar system will displace 15.6 MMBTU's per year of natural gas. Annual cost savings are calculated by the current price of natural gas times the natural gas displaced byt he solar system as determined by historical empirical data. It is recommeded not to install a BTU monitoring system as the cost of the monitoring system will exceed the cost of this project.

***
03C !PROJECT DESCRIPTION
The solar panel will be installed in place of the damaged ground mounted collectors.

***
03D !REQUIREMENT (Why is it needed now)
The project is required to help Fort Huachuca meet the energy reduction goals and renewable energy usage goals in a life cycle cost effective manner. Each collector will reduce operating cost by $96 per year and reduce annual pollution of CO_2 by 5,942 pounds per year and NOx by 21 pounds per year.

***
03E !CURRENT SITUATION (How is the need currently being met)
The loss of the energy normally produced by each collector is provided by the existing gas fired water heater.

```
***
03F  !IMPACT IF NOT PROVIDED
Energy reduction targets will not be met.  Renewable energy
usage targets will not be met.  The operating budget will
not decrease.  There will be no decrease in air pollutants.
The pool heating solar system will continue to not be used
to its maximum potentional.


***
03G  !ADDITIONAL
***
03I  !RELATED PROJECTS


***
/*
/RECALL F 000042372 S    07
07A  !GENERAL JUSTIFICATION DATA
The justification data for this project can be found in this
report and the attached LCCID computer printout.  All
analysis was performed by the Sandia National Laboratories
(SNL) Solar Thermal Design Assistance Center (STDAC).  The
cost of the energy is the cost to the building as of 1 Jan
94 of $6.13 per MMBTU per the Fort Huachuca Base Energy
Coordinator.  Empirical data was supplied to SNL by Ft.
Huachucal personnel.


***
07B  !TRAFFIC ANALYSIS
This project will have no impact on traffic.


***
/*
/RECALL F 000042372 S    08
08B  !PRESENT ACCOMODATIONS AND DISPOSITION
There are no disposal actions for this project.


***
/*
/RECALL F 000042372 S    09
09D  !RPMA DISCUSSION
This project will decrease the utility bill by $96 per year
with no increase in the maintenance budget.
```

```
***
/*
/RECALL F 000042372 S     10
10A  !ANALYSIS OF DEFICIENCIES
Fort Huachuca has some of the best Solar Insolation in the
United States and also has one of the highest industrial
natural gas rates in the nation.


***
/*
/RECALL F 000042372 S     11
11D  !DECISION ANALYSIS
The question was asked if it would be cost effective to
replace the damaged panels of the Barnes Field House solar
pool heating system.  The collector replacement option was
explored by the STDAC from SNL with funding provided by The
Department of the Army, Corps of Engineers.


***
11E  !ECONOMIC ANALYSIS
See attached LCCID computer printout


***
/*
/RECALL F 000042372 S     12
12A  !CRITERIA FOR PROPOSED CONSTRUCTION
It is recommended that the damaged collectors be replaced.
This project should use existing solar equipment and off the
shelf components as required.


***
12B  !USER DISCRETIONARY BLOCK
This would be an excellent project using off the shelf solar
technology.  This project also highlights the mutual support
between the Department of the Army and the Department of
Energy.  The payback period is 3.95 years and the SIR is
4.7.


***
/*
/RECALL F 000042372 S     15
15A  !ENVIRONMENTAL DOCUMENTATION


***
15B1 !SUMMARY OF ENVIRONMENTAL CONSEQUENCES
Reduction of air emissions.
```

***
/*
/RECALL F 000042372 S 19
19A !SUMMARY OF ENERGY REQUIREMENTS
Each solar panel will reduce the use of natural gas by 15.6 MMBTU per year.

***
19B !SUMMARY OF UTILITY SUPPORT
No additional utility support will be required for this project.

***
19C !USER DISCRETIONARY BLOCK
This project will be a success.

***
/*
/RECALL F 000042372 S 21
21A !CA ANALYSIS CONCLUSIONS
This was not done due to the lack of funding and manpower at the installation level.

***
21B !EXECUTIVE SUMMARY OF CA ANALYSIS
N/A

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: HPOOL
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.080
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0001 POOL HTG REFURB
FISCAL YEAR 1994 DISCRETE PORTION NAME: POOL HTG
ANALYSIS DATE: 02-11-94 ECONOMIC LIFE 20 YEARS PREPARED BY: JRA

1. INVESTMENT

A. CONSTRUCTION COST	$ 358.	
B. SIOH	$ 20.	
C. DESIGN COST	$ 0.	
D. TOTAL COST (1A+1B+1C)	$ 378.	
E. SALVAGE VALUE OF EXISTING EQUIPMENT	$ 0.	
F. PUBLIC UTILITY COMPANY REBATE	$ 0.	
G. TOTAL INVESTMENT (1D - 1E - 1F)		$ 378.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	14.53	$ 0.
B. DIST	$ .00	0.	$ 0.	17.63	$ 0.
C. RESID	$ .00	0.	$ 0.	20.79	$ 0.
D. NAT G	$ 6.13	16.	$ 96.	18.59	$ 1778.
E. COAL	$ .00	0.	$ 0.	14.46	$ 0.
F. PPG	$ .00	0.	$ 0.	13.59	$ 0.
M. DEMAND SAVINGS			$ 0.	13.59	$ 0.
N. TOTAL		16.	$ 96.		$ 1778.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) — $ 0.
(1) DISCOUNT FACTOR (TABLE A) — 13.59
(2) DISCOUNTED SAVING/COST (3A X 3A1) — $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
d. TOTAL	$ 0.			0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 0.

4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3Bd1/(YRS ECONOMIC LIFE)) $ 96.

5. SIMPLE PAYBACK PERIOD (1G/4) 3.95 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 1778.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(6 / 1G)= 4.70
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 12.37 %

ECONOMIC & PERFORMANCE ANALYSIS

FOR THE

POOL HEATING SOLAR SYSTEM

	BARNES FIELD HOUSE					
	Pool Heating Solar System					
Gas Savings						
Array size =		54	panels			
Nat. gas savings =		834874	cu. ft./yr			
cu. ft. / lb =		23.6				
HHV (btu/lb) =		23875				
Natural gas displaced per panel per year=				**15.64**	**MMBTU/yr**	(1)
(1) = 834874/54*23875/23.6/1e6						
Cost Estimate						
All copper, unglazed collector =			8.1			
Collector size =			40	sq. ft.		
Labor to install =			34	per panel		
	TOTAL =		**$358**	**per panel**		
Cost Savings						
Natural gas savings per year =			15.64	MMBTU		
Natural gas $ +			6.13	/MMBTU		
	TOTAL SAVINGS +		**$96**	per year		

PERFORMANCE DATA

SUPPLIED BY FT. HUACHUCA

FOR THE

POOL HEATING SOLAR SYSTEM

BARNES FIELD HOUSE
SOLAR POOL HEATING - FORT HUACHUCA, ARIZONA

GENERAL

Fort Huachuca is located in the southeast portion of Arizona at an elevation of 5000 feet above sea level. The area receives a large amount of sunshine all year. Summers enjoy a moonsoon flow from the gulf which results in thunderstorms July through mid-September. Winters are mild with about 2500 degree days, sunny days with overnight lows in the twenties.

Barnes Field House is a gymnasium complex with a wide variety of physical fitness facilities. One of these is a 3500 square foot indoor swimming pool. The pool was heated with a natural gas fired pool heater prior to installation of the solar system.

THE DESIGN

An unglazed 2000 square foot solar system was designed for the pool. The system cost $53,000 or $26 per square foot of collector. The solar system is ground mounted without fences to encourage personnel to become familiar with the the system. It was designed to save 75% of the estimated pool heating energy of 8500 therms or 6407 therms saved. This load was calculated assuming a pool blanket was installed when the pool was not in use. During the design it was noticed that the pool heater responded to cold fronts within several hours of dropping temperatures. This seemed surprising since the pool is indoors and has substantial mass. Cold air was found to be leaking into the pool enclosure through poorly fitting sliding glass doors. This cold air stratified across the pool surface because of its density and caused immediate heat loss. The analysis also included radiation losses from the pool surface to all interior surfaces.

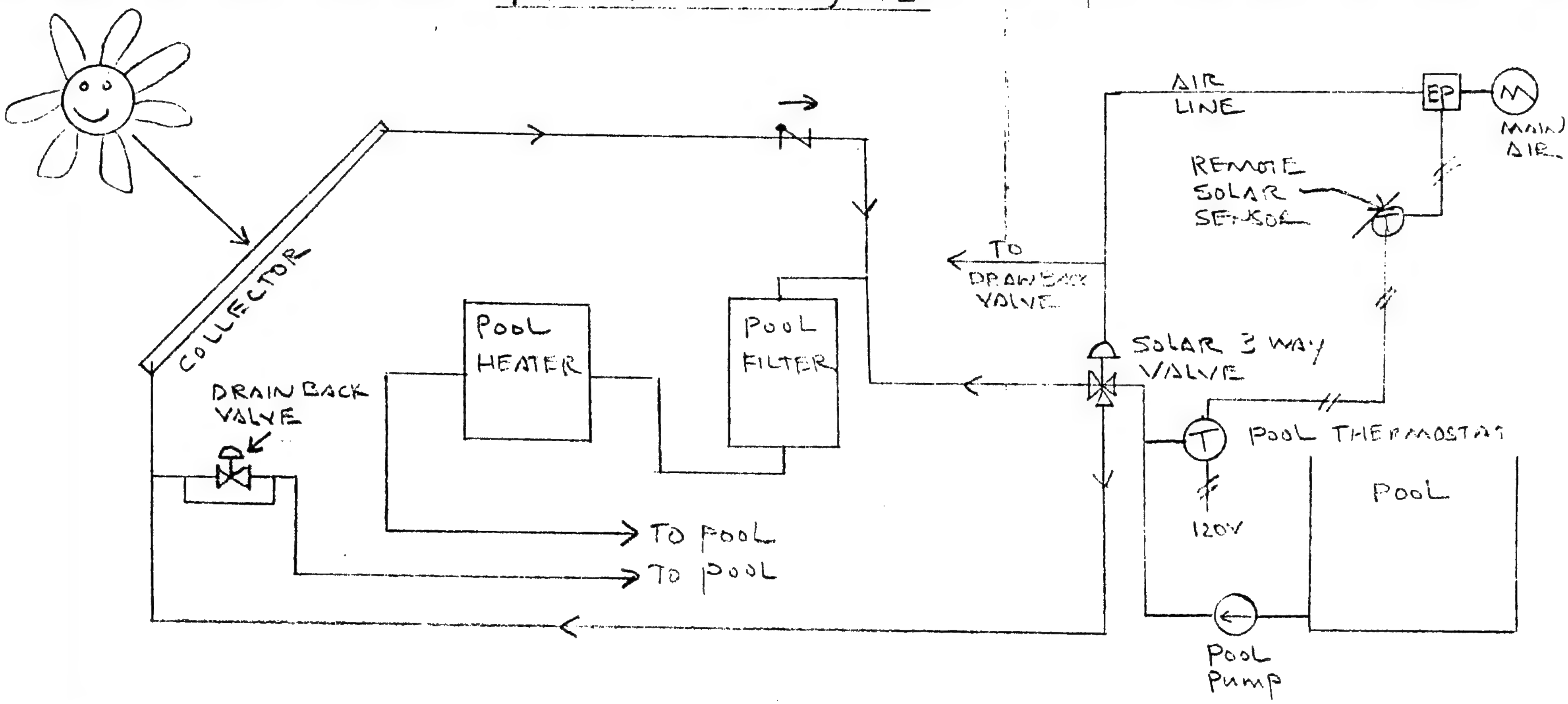
The solar system is activated by two thermostats in series. The first thermostat measures pool temperature. The second thermostat measures the collector temperature. If the pool is calling for heat and the collector temperature is warm, a three way diverting valve actuates which switches flow through the collectors. Maximum temperature rise is 3 to 4 degrees F. across the collectors. When the pool is satisfied or the ~~collectors~~ are cool, the valve will switch to flow bypassing the collectors. Water trapped in the field is drained back to the pool by gravity, making this a drainback system. No differential thermostat is required since the pool temperature never fluctuates more than a few degrees.

ACTUAL SYSTEM OPERATION

The system has operated well since its installation circa 1980. The pool cover was never installed and the pool heat loss was measured at 17,094 therms the first year. The system actually saved 8348 therms or 30% better than forecast. This resulted in a 49% solar contribution for the increased load. First year savings were $2337. Simple payback based on first year savings is about 23 years. Actual payback is less because of increasing gas prices. The system has operated without any problems other than minor collector damage from a vehicle accident.

BRUCE JOHNSON, PE, CEM
SENIOR MECHANICAL ENGINEER, EPS DIVISION, DEH, FT. HUACHUCA, AZ.
12 NOVEMBER 1992

FT HUACHUCA, AZ



1) NO DIFFERENTIAL CONTROLLER REQD.
2) REMOTE SOLAR SENSOR SENSES A FLAT PLATE THAT "LOOKS LIKE" A COLLECTOR THERMALLY.
3) DRAINBACK VALVE HAS A SMALL BYPASS LINE TO DRAIN COLLECTOR IF VALVE FAILS.

FACILITIES ENGINEERING DIR.
FORT HUACHUCA, AZ.

POOL

ENGINEER ____ PROJECT ____ SHEET ___ OF ___

SUBJECT ____

	FT³ SAVINGS	FT³ USED (W SOLAR)	$ SAVINGS
July	52886	68820	148
Aug	57071	73315	160
Sept	105690	107010	296
OCT	168299	172010	471
NOV	27030	184950	76
Dec	94984	213869	266
JAN	70680	260772	198
FEB	76720	184240	215
MAR	69812	262058	195
APR	75060	145200	210
MAY	36642	92163	102
June	—	—	—
	834,874	1,709,407	$2337

.49 OR 49% CONTRIBUTION

1ST YEAR SAVINGS $2337

FIELD DID 30% BETTER THAN ESTIMATED.

FH-FE Form 66, 5 Jun 75

FORT HUACHUCA

SOLAR WATER HEATING OF THE VISITORS QUARTERS

Sandia's Solar Thermal Design Assistance Center (STDAC) was asked to evaluate the use of solar to preheat the hot water in the Visitors Quarters buildings (buildings 43083, 43084, 43085 and 43086). We performed a detailed analysis on Building 43084. If the results of the analysis prove favorable, then we will perform a detailed analysis on three other visitors quarters buildings. Buildings 43084, 5 and 6 each have a storage tank that is charged by the domestic hot water heater. We hoped the system could be re-configured to use the existing storage tank for the solar system and to depend on the existing heaters to satisfy the load when required.

The building's hot water load was measured on November 1 and 2 of 1993 and determined to be 850 gallons per day. Of the 39 rooms, 38 were occupied at the time of testing. On November 2, the mechanical engineer for the base, Bruce Johnson, provided the STDAC with a detailed design for a solar system for this building and asked that the design be reviewed. Our design review is included in the last section of this report.

The load profile showed that the existing hot water heater is not capable of handling the load without the stored hot water during the peak usage period. Because of the limitations of the existing water heater, we decided to incorporated a new solar storage tank that would feed the existing storage vessel.

A 320 square foot solar system would displace 158.7 MMBTU of natural gas each year with a yearly savings of $973. It would reduce CO_2 pollution by 57,096 pounds a year and reduce NO_x by 203 pounds per year. The installed cost was estimated to be $19,700 with a resultant savings-to-investment ratio (SIR) of 0.9 and payback of 21 years.

Building 43085 has a domestic hot water system similar to that of building 43084. This building has only 24 rooms, and the expected hot water load would be 540 gallons per day. Building 43086 has steam boiler that charges a storage vessel via a heat exchanger. This building has 60 rooms and an expected hot water load of 1,350 gallons per day. We do not believed that either of these buildings would offer an advantage over building 43084; therefore, no further analysis was performed.

The above analysis does not account for the increased maintenance cost that would be incurred to maintain this system, nor items such as pump repair, heat exchanger cleaning, etc. These costs were not estimated, because the first analysis resulted in a SIR of less than 1.25.

The STDAC investigated whether a solar preheat system would extend the life of a commercial-sized hot water heater in southern Arizona. Discussions were held with Architect and Engineering firms, the American Gas Association, and the Gas Appliance Manufactures Association. All said they knew of no research or testing in this area; however, all felt that the solar preheat system would have little or no effect on the life of the water heater.

LCCID ANALYSIS

OF THE SOLAR WATER HEATING

FOR THE VISITORS QUARTERS

(Building 43084)

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: VISITORS
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.080
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0002 VISITORS QUARTERS
FISCAL YEAR 1994 DISCRETE PORTION NAME: SDHW
ANALYSIS DATE: 01-27-94 ECONOMIC LIFE 20 YEARS PREPARED BY: JRA

1. INVESTMENT
A. CONSTRUCTION COST $ 19700.
B. SIOH $ 1084.
C. DESIGN COST $ 0.
D. TOTAL COST (1A+1B+1C) $ 20784.
E. SALVAGE VALUE OF EXISTING EQUIPMENT $ 0.
F. PUBLIC UTILITY COMPANY REBATE $ 0.
G. TOTAL INVESTMENT (1D - 1E - 1F) $ 20784.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	14.53	$ 0.
B. DIST	$ .00	0.	$ 0.	17.63	$ 0.
C. RESID	$ .00	0.	$ 0.	20.79	$ 0.
D. NAT G	$ 6.13	159.	$ 973.	18.59	$ 18085.
E. COAL	$ .00	0.	$ 0.	14.46	$ 0.
F. PPG	$ .00	0.	$ 0.	13.59	$ 0.
M. DEMAND SAVINGS			$ 0.	13.59	$ 0.
N. TOTAL		159.	$ 973.		$ 18085.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 13.59
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
d. TOTAL	$ 0.			0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4)$ 0.

4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3Bd1/(YRS ECONOMIC LIFE))$ 973.

5. SIMPLE PAYBACK PERIOD (1G/4) 21.36 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 18085.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(6 / 1G)= .87
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 3.28 %

ECONOMIC & PERFORMANCE ANALYSIS

OF THE SOLAR WATER HEATING

FOR THE VISITORS QUARTERS

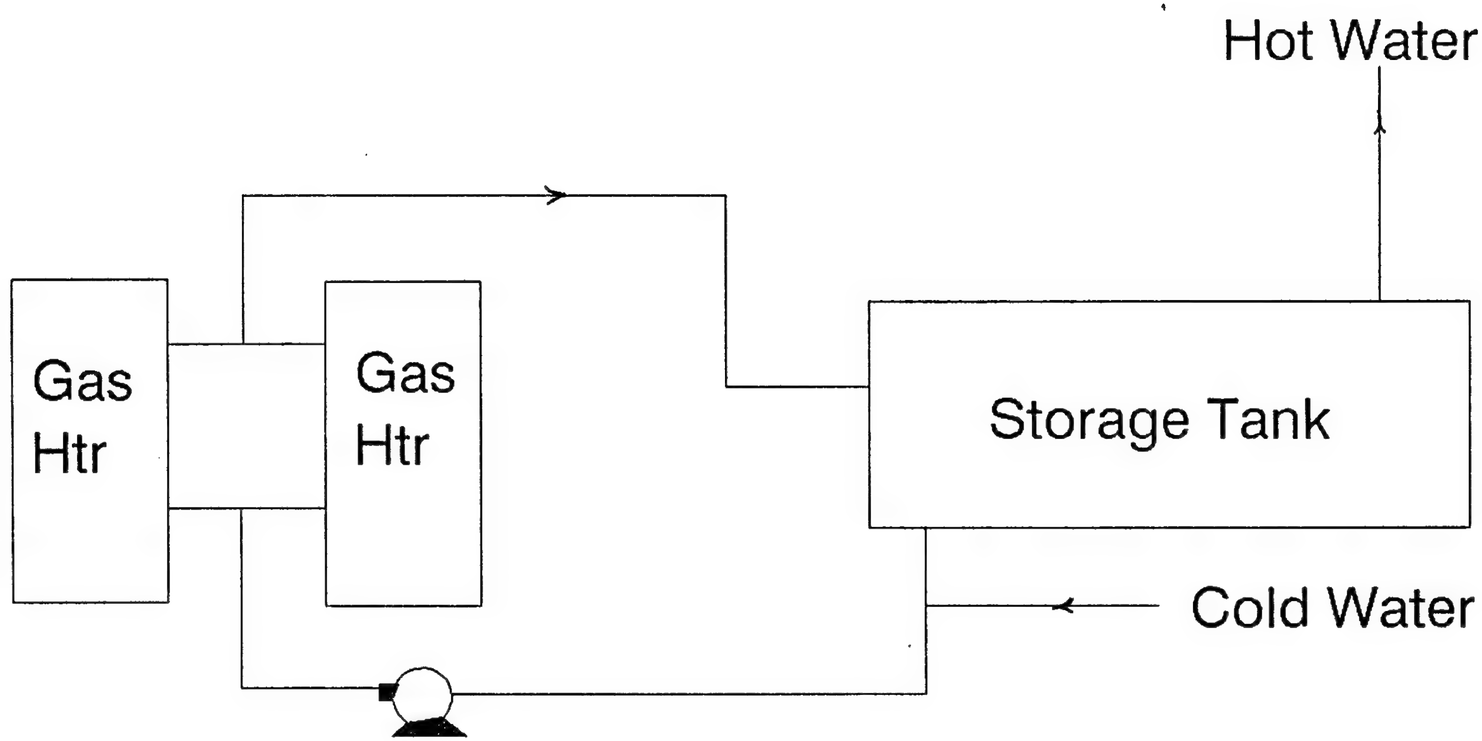
(Building 43084)

FORT HUACHUCA VISITORS QUARTERS BUILDING No. 43084

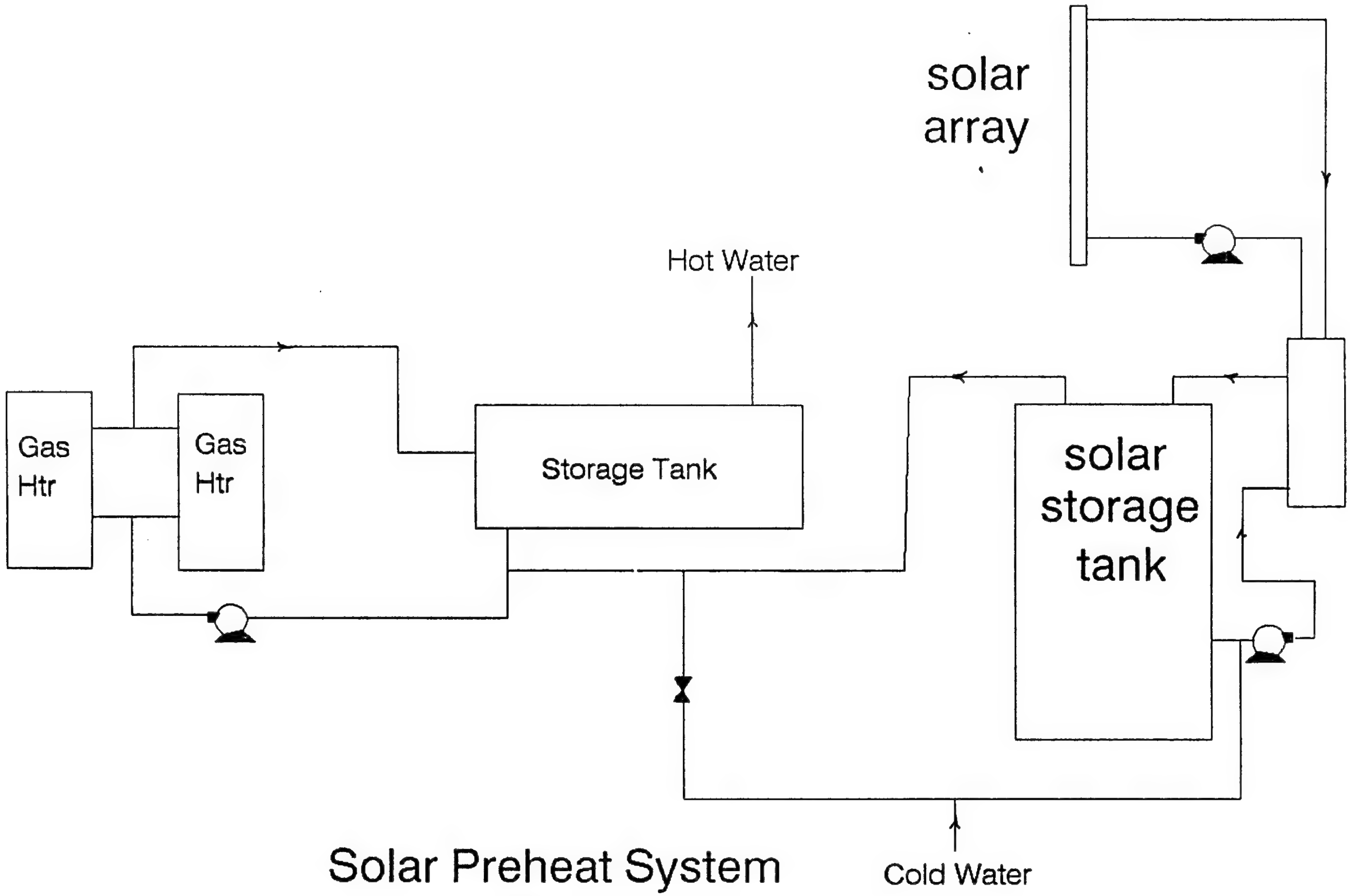
Collector Square feet =	320						
Solar System Efficiency =	0.45						
Load (btu/day) =	509796	(1)					
Boiler Efficiency =	0.70						
Gas Price ($/MMBTU) =	6.13						
					Required	Nat Gas	
Month	Solar Avail	Solar Deliv	Load	Conv. Energy	Nat. Gas	Savings	Savings
	btu/sf/mth	btu/mth	Btu/mth	btu/mth	btu/mth	btu/mth	$/mth
January	51100	7.36E+06	1.58E+07	8.45E+06	1.21E+07	1.05E+07	64
February	54700	7.88E+06	1.43E+07	6.40E+06	9.14E+06	1.13E+07	69
March	68700	9.89E+06	1.58E+07	5.91E+06	8.44E+06	1.41E+07	87
April	75400	1.09E+07	1.53E+07	4.44E+06	6.34E+06	1.55E+07	95
May	78100	1.12E+07	1.58E+07	4.56E+06	6.51E+06	1.61E+07	98
June	72700	1.05E+07	1.53E+07	4.83E+06	6.89E+06	1.50E+07	92
July	66100	9.52E+06	1.58E+07	6.29E+06	8.98E+06	1.36E+07	83
August	68100	9.81E+06	1.58E+07	6.00E+06	8.57E+06	1.40E+07	86
September	66100	9.52E+06	1.53E+07	5.78E+06	8.25E+06	1.36E+07	83
October	66800	9.62E+06	1.58E+07	6.18E+06	8.83E+06	1.37E+07	84
November	54300	7.82E+06	1.53E+07	7.47E+06	1.07E+07	1.12E+07	68
December	49200	7.08E+06	1.58E+07	8.72E+06	1.25E+07	1.01E+07	62
TOTAL		1.11E+08	1.86E+08			**158,667,429**	**$973**
Solar Fraction =	60%						

(1) Load = 850 gpd * 8.33 lb/gal * (140-68)F * 1 btu/lbF

VISITORS QUARTERS SOLAR SYSTEM COST ESTIMATE				
ITEM		QTY	Price	Total
Collectors, 4x8		10	350	3500
Heat exchanger, 10gpm		1	750	750
460 gallon storage tank		1	850	850
Differential temp. controller		1	100	100
1/4 hp pump		1	650	650
1/12 hp pump		1	250	250
15 gallon expansion tank		1	145	145
Collector supports (std mounting hardware)		10	80	800
Copper pipe				0
	3/4 inch, feet	80	0.8	64
	1", feet	150	1.1	165
	2", feet	100	2.15	215
	fittings, valves & misc.	1	1150	1150
Insulation		1	1650	1650
6" core drill		4	8.4	33.6
Thermometers		4	20	80
Controll sensors, freeze stat		3	30	90
Propylene glycol		50	15	750
Electrical, total		1	1650	1650
Labor-install, start-up		100	35	3500
	subtotal			16,393
Profit & Overhead, %			20	3,279
	TOTAL			**$19,671**



Existing Hot Water System
Building 43084



Solar Preheat System
Building 43084

FORT HUACHUCA

SOLAR WATER HEATING
OF
SINGLE FAMILY DWELLINGS

Sandia's Solar Thermal Design Assistance Center was asked to evaluate the use of integral collector storage (ICS) to preheat residential domestic hot water.

According to a study performed by the Florida Solar Energy Center, an ICS will deliver approximately 74% of the daily energy that a flat-plate system will deliver on a square foot basis. In addition, according to a building energy efficiency report, residential domestic hot water heaters, that are natural gas fired, have an operating efficiency of 53%.

An analysis was performed using the INSOL computer program that showed a 40-gallon ICS system would provide 5.09 MMBTU of energy per year. This would displace 9.5 MMBTU per year of natural gas (assuming a 53% hot water heater efficiency) and save \$58 per year at \$6.13 per MMBTU (per Bill Stein).

Base personnel noted that the residential domestic hot water heaters are replaced at a rapid rate. Per Bill Stein said 384 (out of 1950) were replaced last year. At this rate each water heater is replaced every 5 years. This analysis assumes the life of a domestic water heater will be extended 5 years by using the solar preheat system, resulting in a replacement cost savings at years 5 and 15.

The LCCID computer run shows this project to have a savings-to-investment ratio (SIR) of only 1, therefore no further analysis will be performed.

A typical one-panel flat-plate solar system can be installed for \$2600 and will displace 22 MMBTU of natural gas per year for a savings of \$135. The LCCID analysis for this scenario yields a SIR of 0.96.

electricity prices, and other factors. Examples include the installation of occupancy sensors in a section of the World Trade Center, which reduced lighting energy use by 57 percent,[81] and lighting control retrofits in eight commercial buildings that yielded an average 19 percent energy savings, with an average payback of 3.7 years.[82]

Daylighting

The use of natural sunlight, rather than light from electricity, has many attractions. In addition to the electricity savings, daylighting typically offers better views and the feeling of more space. The potential electricity savings are quite high—e.g., a 70 percent reduction in perimeter lighting electricity use.[83] In one case study, a retail/office space was retrofit with daylighting technologies to provide a more attractive space, and although energy savings were not the primary intent, lighting energy use was reduced 59 percent.[84] There can be increased first costs, however, due to the need for additional windows and, depending on climate, an increased space cooling load.[85] Designing a building to exploit daylighting is complex and can require specialized skills.[86]

WATER HEATING

Water heating accounts for about 15 percent of residential and 4 percent of commercial energy use. Slightly more than half of U.S. households use natural gas to heat water and 37 percent use electricity (table 2-11). In residences, hot water is used for personal washing (in showers and baths), clothes washing, dish washing, and other miscellaneous uses. The bulk of hot water use in the commercial sector is in the service sector—in restaurants, laundromats, and other facilities requiring hot water as part of their business.

Table 2-11—Water Heating Fuels in Residential Buildings (1989)

Type	Percent of households
Natural gas	52
Electricity	37
Oil	7
Bottled gas	3
Other	1
	100

SOURCE: U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989*, H150/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 42.

Residential Water Heating Technologies

Essentially all U.S. households have hot water service. In single-family homes and in some multifamily buildings, 40 to 50 gallon water heater tanks are used both to heat and to store hot water. Natural gas-fired tanks typically have somewhat higher first (purchase) costs than electric units,[87] and can cost more to install as well, as they require gas service and external ducting.[88] The costs of operation, however, are typically about 50 percent lower for gas-fired tanks (this will vary depending on fuel costs and unit efficiency).

The efficiency of residential-size water heaters has improved in recent years (figure 2-6), due largely to increased tank insulation, smaller pilot lights, and improved heat transfer from combustion gases to the water in the tank. The most efficient commercially available water heaters sold today use thick polyurethane foam insulation, carefully designed heat trans-

[81] M.A. Piette, F. Krause, and R. Verderber, *Technology Assessment: Energy-Efficient Commercial Lighting*, LBL-27032 (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989), p. 5-4.

[82] K. Greely, J. Harris, and A. Hatcher, "Measured Energy Savings and Cost-Effectiveness of Conservation Retrofits in Commercial Buildings," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 3.103, table 3.

[83] A. Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies*, LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 6-3. Perimeter refers to the area near the windows in a building, as distinct from the core where daylighting often cannot penetrate.

[84] M.A. Piette, F. Krause, and R. Verderber, *Technology Assessment: Energy-Efficient Commercial Lighting*, LBL-27032 (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989), p. 5-2.

[85] The use of fewer electrical lights will reduce space cooling needs; however, this may be more than offset by the increased heat coming from the sun.

[86] A. Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies*, LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 6-2.

[87] Natural gas units are typically about 20 to 30 percent more expensive than comparable electric units, excluding installation and operating costs.

[88] Approximately one-third of households in the United States do not have access to natural gas. U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987*, DOE/EIA-0314(87) (Washington, DC: May 1989), p. 35.

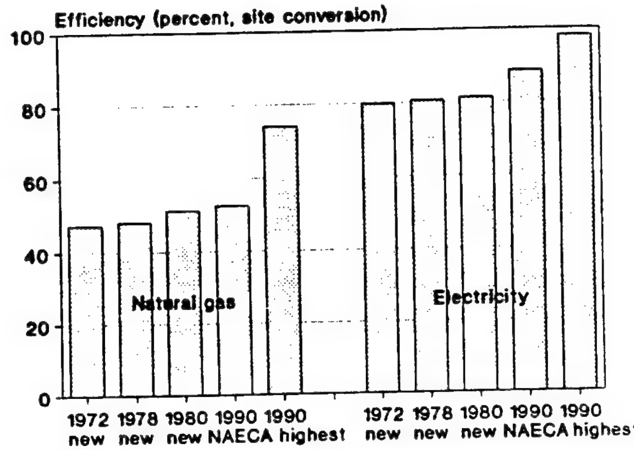
fer surfaces, and electronic ignition, but these features are found only in a few models. As was found for other residential appliances, there is a considerable efficiency difference between the average new water heater and the most efficient commercially available new water heater (figure 2-6).

The costs of the very efficient units are quite high—but it is not appropriate to attribute this additional cost solely to energy efficiency. For example, a 40-gallon gas water heater with an efficiency of 74 percent costs about $780, but this unit has a lifetime warranty,[89] special design to eliminate corrosion, and several other features not found on a $350 61 percent efficient unit.[90] According to a sales manager for a water heater manufacturing firm, the main marketing advantage of the highly efficient unit is the warranty and not the energy efficiency.[91] (Chapter 3 of this report discusses in more detail how energy-using devices are marketed and selected.)

Other methods of improving water heating efficiency include demand reductions, retrofits to existing units, and technical improvements in new units. The simplest method to reduce energy use for water heating is by reducing consumption of hot water. The largest users of hot water in residences are showers and baths (41 percent of hot water), clothes washing (24 percent), and kitchens (27 percent), with the remainder (8 percent) used in bathroom sinks.[92] Low-flow showerheads can reduce shower flow rates by about 50 percent.[93] Although consumer acceptance of these devices is a concern, designs have improved in recent years and consumer satisfaction is reported to be quite high.[94]

Retrofits to existing hot water systems can reduce their energy use. Popular retrofits include tank wrapping (adding a layer of insulation to the outside

Figure 2-6—Trends in the Efficiency of Water Heaters



NOTES: 'New' is shipment-weighted average of all units shipped in that year. 'NAECA' is the minimum allowable according to the national standard. 'Highest' is the most efficient commercially available.

SOURCES: 1972 to 1980: Pacific Northwest Laboratory, *Residential and Commercial Data Book—Third Edition*, PNL-6454 (Richland, WA: February 1988). 1990 NAECA: Public Law 100-12, for a 50 gallon tank. 1990 highest: Gas Appliance Manufacturers Association, "Consumer's Directory of Certified Efficiency Ratings," October 1990, Arlington VA, pp. 134, 163.

of the hot water tank), reducing tank temperature, and insulating hot water pipes. Adding R-11 insulation blankets to water heaters in homes in the Pacific Northwest, at a cost per blanket of about $20, resulted in an average annual savings of 714 kWh per household.[95] A separate study found water heater wrapping to be the most cost-effective building retrofit measure, with an average payback of 0.6 years.[96]

Several new water heating technologies show considerable promise for improved efficiency. Heat pump electric water heaters, which pump heat from an external heat source (usually outside air) into a hot water tank, are commercially available from

[89] For example, one company provides a warranty in effect for as long as the original purchaser owns his or her home.

[90] Costs and efficiencies from "Sears Spring/Summer 1991 Catalog," Sears Roebuck Co., Downers Grove, IL, pp. 1073-1077.

[91] The simple payback considering only the difference in energy efficiency is an unimpressive 15 years.

[92] W. Kempton, "Residential Hot Water: A Behaviorally-Driven System," in W. Kempton and M. Neiman (eds.), *Energy Efficiency: Perspectives on Individual Behavior* (Washington, DC: American Council for an Energy-Efficient Economy, 1987), p. 233.

[93] Measured data from actual showers in Washington State, as reported in B. Manclark, "Low-Flow Showers Save Water," *Home Energy*, vol. 8, No. 4, July/August 1991, p. 28. This does not necessarily mean that the use of low-flow showerheads will reduce shower hot water consumption by 50 percent, as people may take longer showers once the low-flow showerhead is installed.

[94] In one study, the percent of consumers reporting that they were "very satisfied" with their showerheads went from 37 to 56 percent after replacement of old showerheads with new low-flow units. Ibid., p. 29.

[95] M. Brown, D. White, and S. Purucker, *Impact of the Hood River Conservation Project on Electricity Use for Residential Water Heating*, ORNL/CON-238 (Oak Ridge, TN: Oak Ridge National Laboratory, October 1987), pp. xii, 8.

[96] S. Cohen, "Fifty Million Retrofits Later," *Home Energy*, vol. 7, No. 3, May/June 1990, p. 16.

Box 2-F—Plastic Tanks: A Technical Advance That May Hinder Energy Efficiency

The natural turnover in appliance stock has allowed newer, more efficient appliances to penetrate the market. Recent developments in materials, however, may decrease turnover and thereby slow the implementation of new, efficient appliances.

Almost all residential-size hot water storage tanks are made of steel. These tanks typically last 10 to 15 years, and when they fail it is almost always due to corrosion of the steel seam. Recently, however, plastic-lined one-piece tanks have appeared on the market. These tanks are available with warranties that are good for as long the purchaser owns the tank, implying that the manufacturer does not expect these units to fail. Although these units are at present quite efficient—with efficiencies of 94 to 97 percent due to the use of thick insulation, heat traps, and other devices—their use may reduce the use of improved technologies such as heat pump water heaters in the future, as the replacement market will shrink drastically. Furthermore as plastic-lined tanks become more popular and less expensive, they may find use in less efficient electric water heaters.

several U.S. firms. The energy efficiency of these units is in the range of 150 to 340 percent.[97] Costs are quite high—about $900 to $2,000[98]—but may drop in the future if production volumes increase.[99] Add-on heat pump units, which can be retrofit to existing water heaters, can also be used, but here again prices are high.[100] Heat recovery water heaters, which capture waste heat from space conditioning equipment, are available for an installed cost of about $550.[101] Performance of these units depends heavily on climate. A prototype condensing gas water heater, which recaptures the latent heat in the combustion gases, has been built with an efficiency of 83 percent.[102]

Table 2-12—Water Heating Fuels in Commercial Buildings

Fuel	Percent[a]
Natural gas	49
Electricity	40
District heat	9
Fuel oil	4
Propane	2

[a]The approximate percent of commercial building floor space whose hot water is supplied by the corresponding fuel. Total sums to more than 100 as some commercial buildings use more than one fuel for hot water. Excludes commercial buildings with no hot water.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC: June 1991), p. 150.

Commercial and Multifamily Water Heating Technologies

As in residential buildings, natural gas and electricity are the leading fuels for water heating in commercial buildings (table 2-12).[103] The methods and systems used for heating water in commercial buildings vary widely. Many older buildings have a hot water tank that is heated by a submerged coil, heated in turn by the main space-heat boiler. This design is rarely used in new buildings, as it requires the main boiler to be operated year-round to provide hot water. A second design is a storage tank with a smaller, dedicated boiler. This boiler can provide only hot water or can provide both hot water and space heating as necessary. A third type of system is a commercial tank, which is essentially a large-scale version of a residential tank. This last design is increasingly popular, as it is simple and relatively inexpensive to install.

The options for improvements are similar to those for residential systems. Demand reductions, including repairing leaks and reducing temperature settings, can reduce energy use. Retrofits to systems

[97] Efficiencies of over 100 percent are possible as the useful output includes the pumped heat obtained from another source, while the only input is the electricity used to pump the heat from one place to another. Source is EPRI, *Electric Water Heating News*, vol. 4, No. 1, spring 1991, p. 4.

[98] Average costs for an integral (i.e., includes tank) heat pump water heater. Ibid.

[99] Economies of scale in production require higher sales volumes, yet these volumes will not be achieved as long as prices are high.

[100] Probably $450 to $800. EPRI, *Electric Water Heating News*, vol. 4, No. 1, spring 1991, p. 4.

[101] Installed costs vary widely, depending on the specific equipment used and the difficulty of installation. Average value of $550 from Synergic Resources Corp., *Review of Energy-Efficient Technologies in the Residential Sector*, EPRI EM-4436, vol. 1 (Palo Alto, CA: Electric Power Research Institute, February 1986), p. 1-12.

[102] E. Hirst, J. Clinton, H. Geller, W. Kroner, *Energy Efficiency in Buildings: Progress and Promise* (Washington, DC: American Council for an Energy-Efficient Economy, 1986), p. 85.

[103] Much of this discussion applies to large multifamily buildings as well.

can include those used in the residential sector, such as increasing tank insulation, as well as some more innovative features including electronic ignitions, electronic flue dampers, and boiler tune-ups. For example, the addition of an electric flue damper to a 70-gallon natural-gas-fired water heater tank in a recent field test increased efficiency from 61 to 65 percent, with a payback period of 5.3 years.[104]

New technologies for commercial water heating include the use of heat pumps, heat recovery devices, and other methods for integrating water heating into other heating and cooling systems. For example, a heat recovery heat pump recently installed at a large resort complex in Arizona uses heat from the chillers (space cooling devices) to heat water for the laundry, swimming pool, and spa. The new system replaces a natural-gas water heating system and thereby reduces the annual natural gas costs by about $61,000 per year. The estimated payback for the system is 3.5 years.[105]

FOOD REFRIGERATION/ FREEZING

Keeping food cold requires a significant amount of energy—about 10 percent of residential energy use and about 5 percent of commercial sector energy use.[106] The energy efficiency of food refrigeration equipment has improved tremendously in the last 10 to 20 years, and considerable potential for further improvement remains. This section reviews the recent history of refrigeration equipment, the present-day technologies, and the most promising technologies for the future. Residential equipment is emphasized, as it uses the bulk of food refrigeration energy, but commercial technologies are mentioned as well.

Residential Refrigeration and Freezing

Almost every U.S. household has at least one refrigerator, and some—about 14 percent—have two or more.[107] The energy consumption of residential refrigerators tripled from 1950 to 1972, due to increased size (from 7 to 17 cubic feet), addition of energy-consuming features such as automatic defrost, and reduced insulation.[108] In the 1970s, however, several factors led to a sharp drop in refrigerator energy consumption. Increased energy prices, energy consumption labels (required by the Energy Policy and Conservation Act of 1975, Public Law 94-163), and State-level energy efficiency standards (California set minimum refrigerator energy efficiency standards in 1976) all led to the use of improved, more efficient refrigerator technologies. A number of innovations and improvements, rather than a single technical breakthrough, led to a 55 percent drop in the energy consumption of the typical refrigerator from 1972 to 1990 (table 2-13, figure 2-7). Among these improvements were the use of polyurethane foam rather than fiberglass insulation, more efficient motors and compressors, improved door seals, and improved air flow between cold coils and food compartments.

The typical refrigerator sold today is an 18-cubic-foot, top-mount (meaning the freezer is above the refrigerator), automatic defrost unit using about 900 kWh per year.[109] Although this energy use level is far below that of the typical units sold in the 1970s, it is far above that which the Department of Energy (DOE) has determined to be "technically feasible" (table 2-13). According to DOE, it is technically feasible to build a refrigerator using less than 500 kWh per year that retains the features expected by consumers—including 18-cubic-foot interior volume and automatic defrost. A 16-cubic-foot manual

[104] R. Nevitt and V. Stefanson, "Evaluating the Performance of a New High Efficiency Commercial Tank Water Heater," *Proceedings of the ACEEE 1988 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1988), p. 2.155.

[105] EPRI, *Electric Water Heating News*, vol. 3, No. 3, winter 1990-91, pp. 1, 3.

[106] Primary equivalent, see app. 1-B for sources.

[107] U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90) (Washington, DC: May 1991), p. 45. The term "refrigerator" refers to a combination refrigerator-freezer, unless noted otherwise.

[108] "Appliance Efficiency on the Fast Track," *EPRI Journal*, vol. 12, No. 2, March 1987, p. 33.

[109] Sizes given here refer to the sum of the refrigerator and freezer volumes. The adjusted volume (AV), defined as refrigerator volume plus 1.63 times freezer volume, is 20.8 cubic feet.

LCCID & PERFORMANCE ANALYSIS

OF RESIDENTIAL WATER HEATING

USING 40 GALLON BATCH SOLAR PREHEATER

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: BATCH
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.080
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0004 RESIDENTIAL SDHW
FISCAL YEAR 94 DISCRETE PORTION NAME: SDHW
ANALYSIS DATE: 02-14-94 ECONOMIC LIFE 20 YEARS PREPARED BY: JRA

1. INVESTMENT

A. CONSTRUCTION COST	$ 1200.		
B. SIOH	$ 66.		
C. DESIGN COST	$ 72.		
D. TOTAL COST (1A+1B+1C)	$ 1338.		
E. SALVAGE VALUE OF EXISTING EQUIPMENT		$ 0.	
F. PUBLIC UTILITY COMPANY REBATE		$ 0.	
G. TOTAL INVESTMENT (1D - 1E - 1F)			$ 1338.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	14.53	$ 0.
B. DIST	$ .00	0.	$ 0.	17.63	$ 0.
C. RESID	$ .00	0.	$ 0.	20.79	$ 0.
D. NAT G	$ 6.13	10.	$ 58.	18.59	$ 1087.
E. COAL	$ .00	0.	$ 0.	14.46	$ 0.
F. PPG	$ .00	0.	$ 0.	13.59	$ 0.
M. DEMAND SAVINGS			$ 0.	13.59	$ 0.
N. TOTAL		10.	$ 58.		$ 1087.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-)		$ 0.
(1) DISCOUNT FACTOR (TABLE A)	13.59	
(2) DISCOUNTED SAVING/COST (3A X 3A1)		$ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
1. HTR REPLACEMENT	$ 200.	5	.82	164.
2. HTR REPLACEMENT #2	$ 200.	15	.56	112.
d. TOTAL	$ 400.			276.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 276.

4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3Bd1/(YRS ECONOMIC LIFE)) $ 78.

5. SIMPLE PAYBACK PERIOD (1G/4) 17.05 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 1363.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(6 / 1G)= 1.02
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 4.10 %

SUMMARY OF PROGRAM INPUT PARAMETERS -- TMY FILE: tucson.tmy

DAY SKIP: 6 DYS HRLY FILE: NONE COL. AREA: 1.740E+00 SQ. MET.

SITE LATI: 31.0 DEG COL. TILT: 30.0 DEG COL. AZIM: 0.0 DEG

ALBEDO: 0.30 THRESH INSOL: 100. KW TRACKING: FIXED TILT

DAYFILE: dayout.dat

SOLAR RADIATION AVAILABLE TO COLLECTOR

MO	KWH/M2	KWH/COLLECTR	BTU/FT2	BTU/COLLECTR
J	0.190E+03	0.331E+03	0.603E+05	0.113E+07
F	0.185E+03	0.323E+03	0.588E+05	0.110E+07
M	0.234E+03	0.406E+03	0.741E+05	0.139E+07
A	0.248E+03	0.431E+03	0.785E+05	0.147E+07
M	0.257E+03	0.448E+03	0.816E+05	0.153E+07
J	0.231E+03	0.401E+03	0.731E+05	0.137E+07
J	0.233E+03	0.406E+03	0.740E+05	0.139E+07
A	0.225E+03	0.391E+03	0.713E+05	0.134E+07
S	0.224E+03	0.389E+03	0.710E+05	0.133E+07
O	0.224E+03	0.389E+03	0.709E+05	0.133E+07
N	0.165E+03	0.288E+03	0.524E+05	0.982E+06
D	0.159E+03	0.276E+03	0.504E+05	0.944E+06
ANN	0.257E+04	0.448E+04	0.817E+06	0.153E+08

BTU to collector per year = 15.3 MMBTU
Solar system efficiency = 45%
Batch efficiency (compared to flat plate) = 74%
Water heater efficiency = 53%

Natural gas displaced = 15.3 * .45 * .74 / .53 = 9.5 MMBTU/year

LCCID & PERFORMANCE ANALYSIS

OF RESIDENTIAL WATER HEATING

USING 32 SQUARE FOOT FLAT PLATE SOLAR PREHEATER

LIFE CYCLE COST ANALYSIS SUMMARY   STUDY: RESIDENT
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)   LCCID 1.080
INSTALLATION & LOCATION: FT. HUACHUCA REGION NOS. 9 CENSUS: 4
PROJECT NO. & TITLE: 0004 RESIDENTIAL SDHW
FISCAL YEAR 94 DISCRETE PORTION NAME: SDHW
ANALYSIS DATE: 02-14-94 ECONOMIC LIFE 20 YEARS PREPARED BY: JRA

1. INVESTMENT
A. CONSTRUCTION COST $ 2600.
B. SIOH $ 143.
C. DESIGN COST $ 156.
D. TOTAL COST (1A+1B+1C) $ 2899.
E. SALVAGE VALUE OF EXISTING EQUIPMENT $ 0.
F. PUBLIC UTILITY COMPANY REBATE $ 0.
G. TOTAL INVESTMENT (1D - 1E - 1F) $ 2899.

2. ENERGY SAVINGS (+) / COST (-)
DATE OF NISTIR 85-3273-X USED FOR DISCOUNT FACTORS OCT 1992

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	14.53	$ 0.
B. DIST	$ .00	0.	$ 0.	17.63	$ 0.
C. RESID	$ .00	0.	$ 0.	20.79	$ 0.
D. NAT G	$ 6.13	22.	$ 135.	18.59	$ 2507.
E. COAL	$ .00	0.	$ 0.	14.46	$ 0.
F. PPG	$ .00	0.	$ 0.	13.59	$ 0.
M. DEMAND SAVINGS			$ 0.	13.59	$ 0.
N. TOTAL		22.	$ 135.		$ 2507.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 13.59
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
1. HTR REPLACEMENT	$ 200.	5	.82	164.
2. HTR REPLACEMENT #2	$ 200.	15	.56	112.
d. TOTAL	$ 400.			276.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+)/COST(-)(3A2+3Bd4) $ 276.

4. FIRST YEAR DOLLAR SAVINGS 2N3+3A+(3Bd1/(YRS ECONOMIC LIFE)) $ 155.

5. SIMPLE PAYBACK PERIOD (1G/4) 18.72 YEARS

6. TOTAL NET DISCOUNTED SAVINGS (2N5+3C) $ 2783.

7. SAVINGS TO INVESTMENT RATIO (SIR)=(6 / 1G)= .96
(IF < 1 PROJECT DOES NOT QUALIFY)

8. ADJUSTED INTERNAL RATE OF RETURN (AIRR): 3.79 %

```
  SUMMARY OF PROGRAM INPUT PARAMETERS -- TMY FILE: tucson.tmy
DAY SKIP:   6 DYS        HRLY FILE: NONE          COL. AREA:  2.970E+00 SQ. MET.
SITE LATI: 31.0 DEG      COL. TILT: 30.0 DEG      COL. AZIM:    0.0 DEG
ALBEDO: 0.30             THRESH INSOL:   100. KW  TRACKING: FIXED TILT
DAYFILE: dayout.dat
```

SOLAR RADIATION AVAILABLE TO COLLECTOR

MO	KWH/M2	KWH/COLLECTR	BTU/FT2	BTU/COLLECTR
J	0.190E+03	0.565E+03	0.603E+05	0.193E+07
F	0.185E+03	0.551E+03	0.588E+05	0.188E+07
M	0.234E+03	0.694E+03	0.741E+05	0.237E+07
A	0.248E+03	0.735E+03	0.785E+05	0.251E+07
M	0.257E+03	0.764E+03	0.816E+05	0.261E+07
J	0.231E+03	0.685E+03	0.731E+05	0.234E+07
J	0.233E+03	0.693E+03	0.740E+05	0.237E+07
A	0.225E+03	0.668E+03	0.713E+05	0.228E+07
S	0.224E+03	0.665E+03	0.710E+05	0.227E+07
O	0.224E+03	0.664E+03	0.709E+05	0.227E+07
N	0.165E+03	0.491E+03	0.524E+05	0.168E+07
D	0.159E+03	0.472E+03	0.504E+05	0.161E+07
ANN	0.257E+04	0.765E+04	0.817E+06	0.261E+08

BTU to collector per year = 26.1 MMBTU
Solar system efficiency = 45%
Water heater efficiency = 53%

Natural gas displaced = 26.1 * .45 / .53 = 22 MMBTU/year

FORT HUACHUCA

WIND & GEOTHERMAL ENERGY POTENTIAL AT FT. HUACHUCA

Although no existing projects were available for Energy Conservation Investment Program documentation preparation, we made a few telephone calls to try to determine the potential for wind and geothermal energy exploitation.

WIND ENERGY POTENTIAL

According to Andrew Rosenthal of the Southwest Technology Development Institute, wind data was recorded at Ft. Huachuca from 1954 to 1971. The exact location of the wind station is unknown; however, the wind energy information is summarized in the Wind Energy Resource Atlas. This summary is included in this report.

Dennis Elliot of Pacific Northwest Laboratories believes that the ridge may have potential for large-scale, grid-connected, application. He does not believe the flat basin area has potential for wind enrgy usuage.

GEOTHERMAL ENERGY

Jim Witcher of the Southwest Technology Development Institute is not aware of any known geothermal resource at Ft. Huachuca. He says the fort is in a rift zone, so it may have potential. He suggested studying geologic maps, studying existing well data, preparing temperature logs of existing wells, and determining the water chemisty of existing wells, because geothermal activity can leave a tell-tale trace in the water chemistry.

WIND ENERGY DATA

Appendix C

Annual and Seasonal Mean Wind Speed and Power Summaries For Selected Stations in the United States and Its Territories

Wind data from 975 stations in the National Climatic Data Center (NCDC) tape set TD-1440 were analyzed to provide much of the data used to create the National Wind Energy Assessment. For these 975 stations, 1,889 separate periods of record were identified, during which anemometer location, observation, frequency, and data coding frequency were constant. In this appendix, summary information on station identification, location, and annual and seasonal mean wind speeds and wind power densities are presented for these stations and periods.

Stations are grouped alphabetically by state with postal abbreviation information on each period of record following chronologically. The NCDC station number code (WBAN) is used to uniquely identify stations with the same city name. The agency responsible for station operation is identified by the TYP code:

TYP	Type of Station Making Observations
A	Air Force
N	Navy
W	Weather Service
F	FAA

Station location is given by its latitude and longitude coordinates in degrees (DD) and minutes (MM). Positive latitude is north of the equator. West longitudes are less than zero. Station elevation is given in meters above mean sea level. Station location information was largely obtained from the NCDC publication *WBAN Station Numbers* (NCDC 1978).

Period of record information was extracted from the *National Wind Data Index* (Changery 1978). Starting and ending dates, coded YY=Year, MM=Month, and DD=Day, were selected to maximize the length of record. The change in coding frequency from hourly to 3-hourly by the NCDC at the end of 1964 results in many periods ending near 641231 and starting near 650101; many periods of record for Air Force stations end at 701231 at which time the NCDC stopped digitizing Air Force data. The NCDC stopped digitizing navy data on an hourly basis after February 1972. A break in the period of record also occurs if the observation frequency at the stations changed. The OBS code indicates the number of hours per day that observations were taken at the station:

OBS	Hours of Observation Per Day
A	24
B	19-23
C	12-18
D	5-11
E	4
F	Less than 3
Blank	Unknown

Periods of record were most often interrupted by changes in anemometer height or location. Changery's index documents these changes and gives an anemometer height and location history for each station. Anemometer height is reported here in meters above the ground. The LOC code describes the type of structure on which the anemometer was located:

LOC	Anemometer Location
R	Roof-Top
G	Ground Mast
B	Beacon Tower
U	Unknown Location
E	Estimated Wind, No Anemometer

A roof-top location means the anemometer was located on a mast on the roof of a building with the height of the anemometer above ground as given. There is no information on the height of the mast above the roof. A ground mast signifies that the mast, with its base on the ground, is used primarily to support the anemometer. Beacon tower locations mean that the tower is not primarily used to support the anemometer but has other functions. A few early periods of record were coded from estimated wind speeds; no anemometer was available at the site. Anemometers with unknown locations usually also are at unknown heights, which are coded as -99.9.

Annual mean wind speed, in m/s, and annual mean wind power density, in W/m^2, are calculated from all available data for the period of record. Seasonal mean values are based on the following months:

Season	Months Included
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Autumn	September, October, November

Wind Energy Resource Atlas
of the United States
[illegible] 1987

ST	Station Name	WBAN Code	TYP	Lat DD.MM	Long DDD.MM	Elev (M)	Period Start YYMMDD	Period End YYMMDD	OBS	Anem HT (M)	LOC	Mean Wind Speed (M/S) and Wind Power Density (Watt/m²) Annual Spd	Annual Pow	Winter Spd	Winter Pow	Spring Spd	Spring Pow	Summer Spd	Summer Pow	Autumn Spd	Autumn Pow
AL	SELMA	13850	A	32.21	-86.59	50	540303	600304	A	15.2	R	2.7	41	3.2	56	3.0	52	2.3	25	2.5	31
AL	TROY	03878	A	31.52	-86.01	120	690401	701231	C	6.7	G	2.8	34%	3.2	53#	3.4	51%	2.2	18%	2.7	30%
AL	TUSCALOOSA	93806	F	33.14	-87.37	57	490101	541231	A	21.6	B	2.8	46	3.4	69	3.1	59	2.0	18	2.5	38
AR	BLYTHEVILLE	13814	A	35.58	-89.57	80	551101	580331	A	9.1	R	3.5	87	4.0	112	4.4	125	2.2	30	3.1	68
AR	BLYTHEVILLE	13814	A	35.58	-89.57	80	600501	701231	A	4.6	G	3.1	56#	3.6	77#	3.9	86#	2.4	28#	2.6	39#
AR	ELDORADO	93992	F	33.13	-92.48	82	490701	541231	A	17.1	R	3.3	60	4.1	90	3.8	81	2.6	28	3.0	47
AR	FAYETTEVILLE	93993	F	36.00	-94.10	381	490701	541231	A	16.5	R	3.7	96	4.3	132	4.4	138	2.8	46	3.3	77
AR	FLIPPIN	03918	W	36.18	-92.36	215	510701	541231	A	17.7	B	2.9	54	3.7	80	3.5	82	2.2	20	2.5	41
AR	FORT SMITH	13964	W	35.20	-94.22	141	480701	600829	A	9.1	R	3.5	58	3.8	71	4.0	81	3.1	35	3.3	47
AR	FORT SMITH	13964	W	35.20	-94.22	141	600830	781231	A	7.0	G	3.3	46	3.6	60	3.8	62	2.8	26	3.1	37
AR	HARRISON	13971	F	36.14	-93.07	337	480701	500831	A	9.8	R	1.9	21	2.6	34	2.4	35	1.1	4	1.7	17
AR	HARRISON	13971	F	36.16	-93.09	419	670101	681231	A	7.6	R	4.0	73	4.7	120	4.5	84	3.0	31	3.8	60
AR	JACKSONVILLE	03930	A	34.55	-92.09	103	560823	701231	A	4.3	G	2.4	32#	2.7	40#	3.0	47#	2.0	18#	2.1	23#
AR	LITTLE ROCK	13963	W	34.44	-92.14	84	510616	591106	A	19.8	R	4.0	69	4.4	86	4.5	88	3.6	46	3.6	57
AR	LITTLE ROCK	13963	W	34.44	-92.14	84	591107	751214	A	6.1	G	3.5	53	3.9	70	4.1	72	3.0	30	3.2	42
AR	LITTLE ROCK	13963	W	34.50	-92.15	172	751215	781231	A	9.8	G	3.3	49	3.8	71	3.5	56	2.7	29	3.0	40
AR	PINE BLUFF	93988	W	34.10	-91.56	63	481001	540213	A	11.3	R	3.4	62	4.0	86	3.9	81	2.7	32	2.9	47
AR	TEXARKANA	13977	F	33.27	-94.00	112	480701	530831	A	9.8	R	4.0	87	4.7	128	4.5	112	3.4	42	3.8	71
AR	TEXARKANA	13977	F	33.27	-94.00	112	540901	590609	A	9.8	R	3.7	69#	3.8	83#	4.1	87#	3.3	50#	3.3	54#
AR	TEXARKANA	13977	F	33.27	-94.00	112	590610	640831	A	8.2	G	3.4	53#	3.7	66#	4.0	78#	2.9	31#	3.1	43#
AR	TEXARKANA	13977	F	33.27	-94.00	112	640901	680831	A	6.1	G	3.4	44	3.7	57	4.0	65	2.8	24	3.0	31
AR	WALNUT RIDGE	93991	W	36.08	-90.56	84	490401	541231	A	9.1	R	3.2	62	3.7	85	3.7	87	2.6	33	2.8	48
AR	WALNUT RIDGE	93991	W	36.08	-90.56	84	600101	651231	A	9.1	R	3.4	64	4.0	81	4.2	91	2.7	38	2.8	47
AZ	CHANDLER	23104	A	33.18	-111.40	412	490101	530331	A	-99.9	U	1.8	21	1.5	17	2.2	26	2.1	24	1.6	16
AZ	CHANDLER	23104	A	33.18	-111.40	412	530501	560331	A	14.6	R	2.5	32	1.8	19	2.6	37	3.1	47	2.4	28
AZ	CHANDLER	23104	A	33.18	-111.40	412	570501	601231	A	11.9	R	1.7	14	1.1	7	2.0	17	2.1	20	1.3	10#
AZ	CHANDLER	23104	A	33.18	-111.40	412	651001	701231	C	4.0	G	2.7	35%	2.1	25%	3.0	41%	3.3	46%	2.4	30%
AZ	DOUGLAS	93026	F	31.27	-109.36	1252	481101	541231	A	10.4	R	3.1	64	2.9	64	3.9	109	2.9	42	2.6	41
AZ	FLAGSTAFF	03103	W	35.08	-111.40	2133	520101	611031	D	9.1	R	3.8	77*	3.8	82*	4.4	102*	3.3	55*	3.6	69*
AZ	FLAGSTAFF	03103	W	35.08	-111.40	2133	611101	641231	A	9.1	R	3.1	45	3.2	49	3.7	61	2.9	34	2.7	35
AZ	FLAGSTAFF	03103	W	35.08	-111.40	2133	651007	781231	A	6.1	G	3.2	42	3.3	41	3.7	59	3.0	32	3.1	36
AZ	FORTHUACHUCA	03124	N	31.35	-110.20	1422	541001	710731	A	4.0	U	3.0	45	2.7	43	3.8	74	3.0	37	2.6	27
AZ	GILA BEND	03148	A	32.53	-112.43	262	680901	701231	D	4.0	G	2.5	41#	2.1	23#	3.0	70#	2.5	43#	2.3	35#
AZ	GILA BEND	23168	W	32.53	-112.43	261	481101	541231	A	7.6	R	3.5	51	3.3	44	3.8	68	3.6	53	3.3	41
AZ	PAYSON	93139	W	34.14	-111.20	1497	490101	511231	A	6.1	R	2.3	20	2.2	20	2.7	29	2.2	15	2.1	14
AZ	PHOENIX/LITCH.	93105	N	33.26	-112.22	292	500101	530310	C	16.8	R	2.9	42*	2.5	31*	3.3	65*	3.2	47*	2.5	25*
AZ	PHOENIX/LITCH.	93105	N	33.26	-112.22	292	550311	630131	C	13.7	R	2.4	28*	1.9	19*	2.8	44*	2.7	30*	2.1	18*
AZ	PHOENIX/LUKE	23111	A	33.33	-112.22	331	530501	590331	A	9.1	R	2.1	26	1.6	17	2.7	38	2.5	32	1.7	18
AZ	PHOENIX/LUKE	23111	A	33.33	-112.22	331	590501	701231	A	3.7	G	2.8	41#	2.3	29#	3.2	53#	3.3	53#	2.4	27#
AZ	PHOENIX/SKY	23183	W	33.26	-112.02	339	480101	521218	A	9.1	R	2.1	17	1.8	12	2.4	21	2.4	21	1.9	13
AZ	PHOENIX/SKY	23183	W	33.26	-112.01	339	521219	580528	A	9.8	R	2.3	26	1.9	18	2.6	36	2.6	31	2.0	20
AZ	PHOENIX/SKY	23183	W	33.26	-112.01	339	601207	750918	A	5.5	G	3.1	35	2.7	26	3.3	42	3.4	41	2.9	30
AZ	PHOENIX/SKY	23183	W	33.26	-112.01	339	750919	781231	A	11.0	R	3.6	49	3.1	38	3.8	62	3.9	58	3.4	41
AZ	PRESCOTT	23184	F	34.39	-112.26	1530	480101	641231	A	11.3	R	3.8	73	3.3	56	4.6	112	3.9	69	3.5	53
AZ	PRESCOTT	23184	F	34.39	-112.26	1530	650406	781231	A	6.1	G	3.7	56	3.5	48	4.2	79	3.6	50	3.4	44
AZ	TUCSON/DAVIS	23109	A	32.11	-110.55	797	490101	530331	A	9.1	R	2.8	52	2.9	57	3.2	65	2.8	46	2.5	38
AZ	TUCSON/DAVIS	23109	A	32.11	-110.55	797	560401	700831	A	4.0	G	2.7	35#	2.6	34#	2.9	38#	2.8	37#	2.6	31#
AZ	TUCSON/INT.	23160	W	32.07	-110.56	789	481001	490916	A	11.0	R	3.7	69	3.6	77	3.7	62	3.6	55	3.7	84
AZ	TUCSON/INT.	23160	W	32.07	-110.56	789	490917	581014	A	10.1	R	3.1	48	3.0	50	3.3	51	3.1	39	3.1	50
AZ	TUCSON/INT.	23160	W	32.07	-110.56	789	581015	670731	A	7.0	G	4.1	75	4.0	72	4.4	85	4.1	70	4.0	73
AZ	TUCSON/INT.	23160	W	32.07	-110.56	789	670801	781231	A	6.1	G	3.8	67	3.6	65	4.1	78	3.9	59	3.8	66
[illegible]	[illegible]	23194	W	35.01	-110.44	1488	510812	590206	A	11.3	R	3.7	84	3.1	69	4.5	140	3.9	78	3.2	54
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	90	3.3	[illegible]	4.8	149	4.2	84	3.5	62

OTHER INVESTIGATIONS

- Lo-Mit 1 Roof Coating
- Instantaneous Water Heaters
- Vendor Information
- Design Review, Building 43084
- July 1993 Site Survey Report

FORT HUACHUCA

OTHER INVESTIGATIONS

LO-MIT 1 ROOF COATING

This type of radiant barrier roof coating is typically spray applied on the inside surface of the roof deck and is most effective for lowering air conditioning loads. Lo-Mit 1 can be applied to the exterior of the roof; however, test data is limited on this type of application.

The Florida Solar Energy Center (FSEC) has developed FSEC 3.0, a building energy computer program that can model different roof surface emittance and solar absorptance, and their effects on heat flow into a building. Phillip Fairey of FSEC can perform a detailed analysis of the effects of using a radiant barrier roof coating on a specific application for approximately $20,000.

Sales information regarding Lo-Mit 1 roof coating is included in this report.

INSTANTANEOUS WATER HEATERS

The Solar Thermal Design Assistance Center was asked to investigate the compatibility of residential instantaneous water heaters with solar preheat. We were able to locate one brand that claims compatibility. Aquastar manufactures a model that is designed to accept preheated water. They supply instantaneous heaters that will produce from 1.8 gpm to 3.25 gpm at 60 degree temperature rise. These are somewhat expensive water heaters, as the larger unit sells for around $700.

Sales information regarding instantaneous water heaters is included in this report.

LO-MIT 1

VENDOR INFORMATION

SOLEC™
Solar Energy Corporation
Box 3065
Princeton, NJ 08543-3065 U.S.A.
Phone 609-883-7700
FAX 609 [illegible]

Thank you for inquiring about our **LO/MIT-I** Spray Applied Radiant Barrier technology. Product information and editorial coverage is enclosed.

LO/MIT-I is the only spray applied low emissivity radiant barrier on the market today. **LO/MIT-I** is the only spray applied radiant barrier that has been tested by the Florida Solar Energy Center and is accepted under GSA contract by the U.S. Government.

LO/MIT-I may be easily applied to the underside of roof decks during the construction process, replacing costly and cumbersome foil radiant barriers as an interior radiant barrier. **LO/MIT-I** may also be used as an exterior radiant barrier roof coating where it has been shown to lower building skin temperatures 20-50°. Used either as an interior or exterior coating, **LO/MIT-I** can substantially lower air conditioning costs and positively effect heating costs.

Architects, builders and contractors can find specifications for **LO/MIT-I** in the AIA Masterspec Guide, section 07210 "Building Insulation", pages E1-E9 and 11-12, and the ICAA Commercial Insulation Products Guide, section "K", Radiant Barriers.

If no distributor is listed on the top of the silver product brochure, please call 609-883-7700 (FAX:609-497-0182) for pricing and technical information.

Again, thank you for considering **LO/MIT-I**, the world's only spray applied radiant barrier.

Most sincerely,

SOLAR ENERGY CORPORATION

NOTE: To remain on our mailing list, please contact us with any changes to the above address.


LO/MIT-I™ RADIANT BARRIER ROOF COATING
The only high reflectivity AND low emissivity roof coating available.
■ Dramatically decreases energy costs; increases occupant comfort
■ Low cost, rapid payback
■ Reduces roof skin temperatures 20°-50° F
■ Fire retardant to 1000° F+
■ Greatly extends roof life; lessens roof movement
■ Excellent adhesion, flexibility and weatherability
■ Easily applied to all roof surfaces
■ GSA contract for all US Government agencies
THE HEAT STOPS HERE
SOLAR ENERGY CORPORATION
PO Box 3065
Princeton, New Jersey 08543-3065, USA
Tel: 609-883-7700 Fax: 609-497-0182

LO/MIT-I T.M.

RADIANT BARRIER COATING

For Energy Conservation and Light Reflection

LO/MIT-I is a silver colored, non-thickness dependent, low emissivity coating. Its superb ability to reflect both heat (infrared radiation) and light make it an excellent, low cost substitute for metallic foils or metallized plastic films. High temperature tolerance, excellent adhesion and the ability to produce uniformly low emissivities on a wide variety of substrates make LO/MIT-I unique in the field of high technology coatings.

OPTICAL CHARACTERISTICS

Laboratory application of LO/MIT-I on glass substrates has lowered emissivity from .86 to .22 and increased spectral reflectivity from 7.3% to 85%. LO/MIT-I can be applied to a wide variety of substrates and normally will create a surface emissivity of .21-.26, and a spectral reflectivity of 81%-85% depending on the substrate used. The chart on the rear of this bulletin shows optical properties on specific materials.

CONSTITUENTS

Aromatic hydrocarbons, aliphatic ketones, proprietary pigments and binders.

SOLVENT

Solsolv 301 or xylene.

VISCOSITY

29 seconds #1 Zahn's cup

HARDNESS

Extremely durable 3H hardness [illegible] minutes at 450°F. Ambient cure hardness [illegible]. Extremely flexible even when heat cured.

DEGRADATION & OUTGASSING

Unaffected by UV or elevated temperatures. Thermally tolerant to 1000° F (538°C). No outgassing when correctly cured.

COVERAGE

400-800 square feet/gallon, depending on surface and application method.

ASTM STANDARD

LO/MIT-I conforms to a standard presently being promulgated for Interior Radiation Control Coatings (IRCC), ASTM Subcommittee C16.21.

MIXING

Coating supplied ready for use. No thinning is required or suggested. Shake well before using. If possible, agitate during application.

SURFACE PREPARATION

Normally, adhesion is the only factor that will be affected by surface preparation. Optical properties will remain constant except on surfaces that are very porous such as brick and cement. To improve optical properties on porous substrates appropriate fillers and primers may be used to increase surface smoothness. This will also increase coverage. On metallic substrates, such as cold rolled or galvanized steel that may be subject to possible corrosion or oxidation, appropriate primers should be used before applying LO/MIT-I. When the surface is already primed or painted, apply a test patch of LO/MIT-I to ascertain that the prepared surface is compatible with the solvents used in LO/MIT-I. Plastics may require surface treatment to increase adhesion and should be tested for compatibility with LO/MIT-I. Most building materials such as wood, plasterboard, paper faced insulation batts [illegible] and painted metal roof decking require no [illegible] preparation except that they be clean and dust free. [illegible] allowed to cure [illegible] one month [illegible] LO/MIT-I.

Any surface preparation [illegible] in this section should be referred [illegible] Department.

APPLICATION

Air Atomization: Use DeVilbiss pressure gun #JGA-502-704-FX; gun pressure of 30 psi (2.11 kg/cm²); tank pressure of 4-6 psi (.14-.42 kg/cm²). Remote paint supply pots should be equipped with an air driven agitator to keep coating thoroughly mixed during application.-OR-DeVilbiss suction gun #JGA-502-43-FF, gun pressure of 25 psi (1.76 kg/cm²). Needle adjustment = ½ open. Hold spray gun 8-14" from work. Spraying at the lower pressure (25-30 psi) indicated will lessen overspray and effect better coverage. Use 2 horsepower or larger compressor.

Airless and Electrostatic: Test airless and electrostatic equipment for compatability with LO/MIT-I before using. Remote paint supply pots should be equipped with an air driven agitator to keep coating thoroughly mixed during application.

Portable Touch Up Sprayer: The SOLEC Model PS-1 portable sprayer is a low cost, disposable, self-contained spray device for the application of LO/MIT-I or any low viscosity paint where power is unavailable. Surface to be coated should not exceed 50 square feet. Ask for bulletin PS-1.

Brush and Roller: LO/MIT-I may also be applied using a solvent resistant paintbrush or roller. However, coverage may be substantially reduced.

Note: Good ventilation is necessary for operator safety and drying and curing of the applied coating.

CLEAN UP

Clean application equipment with Solsolv 301 or Xylene. Use Isopropyl Alcohol for operator clean up and removal from clothing.

DRYING AND CURE

Coating will skin dry within one minute after application. Drying to touch will generally occur within 15 minutes to one hour depending on ambient temperature and humidity. Curing can be accelerated by application of heat up to 500°F (260°C) for 4 to 30 minutes. Experimentation will determine the best curing procedures for your particular environment.

STORAGE

Keep at room temperature in tightly sealed container. Keep out of direct sunlight to avoid pressure increase in container. Full containers will remain usable for 1 year from date of manufacture.

CAUTION

Contains flammable solvents. Do not expose to elevated heat or open flames. Use with adequate ventilation and avoid excessive breathing of vapor or spray mist. Avoid contact with eyes. OSHA regulations, Sections 1915.24—Painting, 1915.25—Flammable Liquids and 1915.82—Respiratory Protection give additional helpful safety suggestions.

FIRST AID

Remove from skin using isopropyl alcohol and warm soapy water. In case of contact with eyes, flush with clean water for at least 15 minutes and get medical attention. If swallowed, get immediate medical attention. If headache, dizziness or nausea result from excessive inhalation of vapors, remove to fresh air and administer oxygen if necessary.

SOLAR ENERGY CORPORATION, BOX 3065, PRINCETON, NJ 08543-3065, U.S.A.

PACKAGING

Steel containers. Quarts, gallons, 5 gallon tight head pails. Weights including containers: Quart (.95 liters) = 2.5 lbs. (1.13 kilos), Gallons (3.79 liters) = 8.2 lbs. (4.24 kilos), 5 gallons (18.93 liters) = 42.5 lbs. (21.66 kilos).

ORDERING AND PRICING INFORMATION

Contact factory at 609-883-7700 for name of your local distributor, pricing and availability. F.O.B. Ewing, N.J. Shipping and packaging extra. Available for export.

Terms: Net 30 days for D&B rated firms.

U.S. GOVERNMENT PURCHASERS:

LO/MIT-I is available through GSA: Contract #TFTC-88-CK-NIIS-01 effective 7/1/89–Section Heading: 80 Brushes, Paint, Sealers & Adhesives. GSA, Proc. Div. (9FTP10-C-M) GSA Center, Auburn, WA 98001.

TECHNICAL SERVICES DEPARTMENT

Contact factory at 609-883-7700, 9-5 pm, EST
or fax 609-497-0182, 24 hours a day.

ACCESSORIES & ADDITIONAL PRODUCTS

PS-1, Portable Touch Up Sprayer, a low cost, self-contained, disposable application device.

SOLKOTE HI/SORB-II, spray applied selective coating.

SOLKLEAN 101, Production metal cleaner.

SOLKLEAN 201, Water based aluminum conversion coating.

SOLSOLV 301, Low cost replacement solvent for Xylene.

ISOPROPYL ALCOHOL, For clean-up of LO/MIT-I coatings.

IMPORTANT NOTICE TO PURCHASER

This bulletin is an introductory summary of LO/MIT-I Radiant Barrier Coating. The information provided is based upon typical installation conditions and tests we believe to be reliable. However, due to a wide variety of possible use conditions, SOLEC does not guarantee that typical values expressed will necessarily be obtained. The following is made in lieu of warranties, expressed or implied, including merchantability.

Seller's only obligation shall be to replace such quantity of t. product proved to be defective. Seller shall not be liable for any injury, loss or damage, direct or consequential, arising out of the use of or inability to use the product. Before using, user shall determine the suitability of the product for their intended use, and user assumes all risk and liability whatsoever in connection therewith.

No statement or recommendation shall have any force or effect unless in an agreement signed by officers of seller and user.

RESEARCH FACILITIES

The Solar Energy Corporation maintains a complete laboratory for the analysis of optical coatings. Our low cost services for the analysis of optical surfaces are used by many large manufacturers. Please contact us for prices.

LO/MIT NOTES

The Solar Energy Corporation publishes bulletins called LO/MIT NOTES on the application and useage of LO/MIT-I. The following bulletins are available, free, to interested parties:

Title	Subject	Application
EC/RC001	Case Study/Energy Conservation	Roof Coating
RB/IRCC	LO/MIT-I/Questions & Answers	Interior Radiant Barrier

OPTICAL PROPERTIES OF SELECTED SUBSTRATES

Substrate	Emissivity Before LO/MIT Applied	Emissivity After LO/MIT Applied	Diffuse Reflectivity Before LO/MIT Applied	Diffuse Reflectivity After LO/MIT Applied
brick (red clay)	.92	.36	36%	71%
cement block	.93	.37	32	66
glass (soda lime)	.86	.22	7.3	85
galvanized steel (bright)	.03	.25	77	84
galvanized steel (dull paint lock)	.57	.26	15	82
paper (kraft)	.80	.24	48	81
plasterboard	.90	.21	55	85
plywood	.72	.22	46	81
poly carbonate (clear)	.84	.22	8.6	84
polypropylene (opaque)	.90	.23	8.1	84
steel, cold rolled, primed	.87	.25	22	83
steel, cold rolled, unprimed	.10	.23	57	84
steel, 316 stainless	.19	.23	59	84

LO/MIT-I Application Ideas

Aircraft

LO/MIT-I is extremely lightweight (less than .05 oz./ft²). It may be effectively used as a heat shield on many aircraft components including wiring harnesses, cowlings, fire walls and electronic components. It is also an excellent coating for balloon fabrics.

Automotive

LO/MIT-I may be used as a low cost, lightweight heat shield on many automotive components including wiring harnesses, battery boxes, exhaust systems, air conditioning ducts, fire walls, intake manifolds, fuel pumps, rubber hoses, shock absorber boots, floor pans, electronic and plastic components.

Building and Construction

LO/MIT-I is a low cost substitute for metallic or metallized plastic foils. Wherever these products are used for energy conservation in new or retrofit construction, spray application of LO/MIT-I will generally prove to be as effective at half the cost. In many instances, where it may be impractical to staple or tack reflective radiant barriers, LO/MIT-I may be easily spray applied.

Daylighting

Since LO/MIT-I exhibits a high diffuse reflectivity on many building materials, it may be effectively used to enhance daylighting and lower illumination costs.

Energy Conservation

The use of LO/MIT-I on ceiling and wall surfaces can result in substantial heating and cooling energy savings. (See Radiant Barriers, Building and Construction, Metal Buildings.) Also, in factory buildings and warehouses, the application of LO/MIT-I to interior ceiling surfaces may raise winter radiant temperatures and increase ceiling reflectivity, thereby lowering both heating and lighting costs.

Metal Buildings

LO/MIT-I, when applied to the exterior of metal buildings, has been shown to lessen building skin temperatures in excess of 30°F (16 C) in 95 F (35 C) ambient environments. This can lead to substantial decreases in heating and air conditioning costs.

Ovens, Process Piping, Power Generation Equipment

LO/MIT-I when applied to the exterior surfaces of boilers, ovens or high temperature process piping can effectively block thermal radiation and may lead to substantial efficiency increases.

Plastics

Whenever plastics are subjected to elevated temperatures, surface application of LO/MIT-I may lessen degradation due to adverse thermal environments. In many cases, lower cost and lower weight plastics may be used when they are coated with LO/MIT-I.

Radiant Barriers

Recent tests by the Florida Solar Energy Center (FSEC) indicate that the role of radiant heat transfer, particularly in hot, sunny climates, may be much more important than recently recognized. In these climates, heat gain prevention is often more critical to the energy performance of a building than stopping heat loss. Application of LO/MIT-I to the undersides of roofs and cavity wall surfaces creates an extremely effective radiant barrier that may lead to substantial energy savings at lower installed per square foot costs than aluminum foil or metallized plastic films.

Reflectors

LO/MIT-I exhibits excellent diffuse reflectivity on many substrates. It may be used as a low cost reflective surface in lighting fixtures, control panels and many other applications where reflectivity is needed.

Roof Coating

LO/MIT-I will lower roof skin temperatures 20-40°F. It is unaffected by UV radiation and highly reflective to infrared. It will greatly extend roof life and may be brushed, rolled or spray applied to bitumen, PVC, EPDM, asphalt, tar and gravel, foam, shingle, tile, steel and most other roofing surfaces. It is hydrophobic and tends to be self cleaning. Field testing in Southern climates has shown energy savings from 15% to in excess of 30% when LO/MIT-I is used as a reflective roof coating.

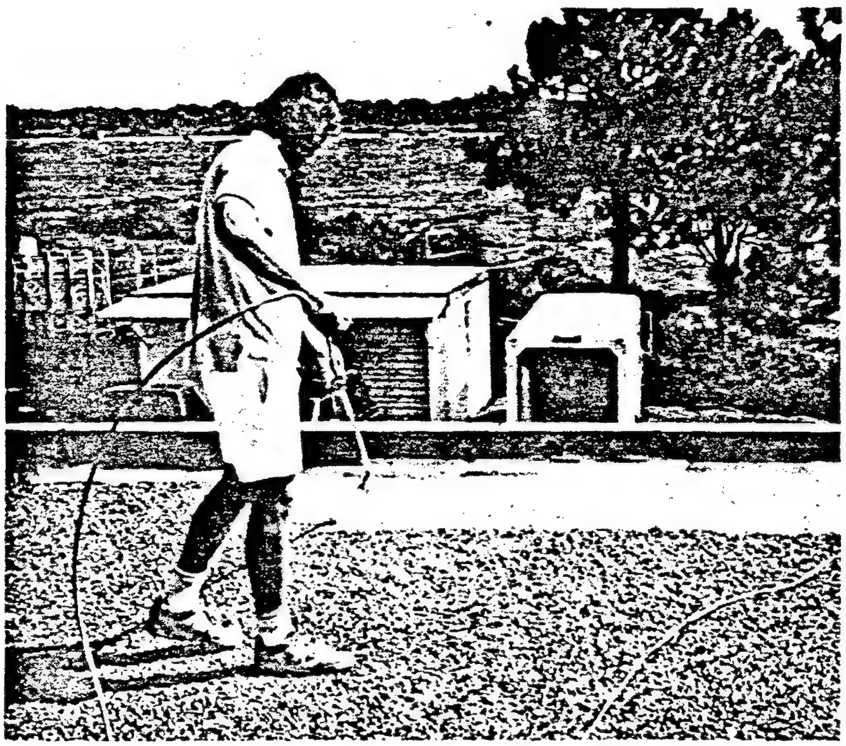
Selective Surfaces

High emissivity surfaces such as glass or cement, when coated with LO/MIT-I, exhibit low emissivities of .22-.30. By overcoating the LO/MIT-I surface with SOLKOTE HI/Sorb-II spray applied selective coating, a semi-selective surface exhibiting emissivities of .42-.50 and absorptivities of 95 to 97 may be achieved. At an installed cost of 12 to 17 cents per square foot, substantial cost savings can be achieved over the use of selective metal foils.

REV. 5/93

Spray-applied radiant barriers

A new generation of energy-saving radiant barriers can be sprayed on the underside of the roof deck or on the roof surface



Radiant barrier coating is applied to the roof of the National Weather Service Building in Daytona Beach, FL.

By William T. Guiney

Keeping a building cool through the use of a reflective insulation or a radiant barrier system under the roof has been shown to be an effective method for reducing interior temperatures and for lowering air conditioning loads. Now this same technology can be employed on rooftops using recently developed spray-applied radiant barriers.

Radiant barriers, when applied to the inside of an attic or interior walls of a building, work by blocking the heat radiating into the building from the hot roof and sidewalls.

William T. Guiney is president of State Energy Consultants Inc., a state of Florida-certified solar contractor that provides consulting services to residential and commercial building owners.

The heat gained from the exterior surfaces exposed to solar radiation is transferred to the interior building components, such as floors and insulation, by infrared radiation. Most interior building components, such as wood, drywall and insulation systems are good absorbers of this infrared radiation.

The result of using radiant barriers for blocking infrared radiation is cooler interior spaces and insulation systems that can perform more effectively.

Typically, laminated aluminum foils or aluminized plastic films have been the most prevalent radiant barrier products available. Now, a unique spray-applied low emissivity paint, LO/MIT-1, is available and is proving to be almost as effective on interior surfaces as traditional radiant barriers. It can also be used on exterior surfaces, where it is almost impossible to use foil or plastic products.

Application techniques

Interior foil radiant barriers can be installed directly on the underside of the roof deck, draped over the top of the trusses before the deck is put in place, or stapled to the underside of the top truss chord.

The spray-applied radiant barriers are sprayed directly on the underside of the roof deck, lowering the ability of the wood deck to emit radiant heat to the inside of the building.

The Reflective Insulation Manufacturers Association recommends that perforated or non-perforated radiant barriers *not* be applied directly on top of existing insulation on the attic floor.

This application method could lead to moisture entrapment below the radiant barrier, and it has been proven that dust accumulation on an upward facing radiant barrier surface will degrade its performance.

Many contractors have questioned whether radiant barriers shorten roof life by increasing the temperatures of the roofing materials. Tests at the Florida Solar Energy Center have shown an increase in roof skin temperatures of less than two degrees Fahrenheit when radiant barriers are used in the attic space.

Thus, radiant barriers should not have any effect on the roof's longevity. These same tests also showed a 20 degree temperature reduction at the insulation level, verifying how effective radiant barriers are in reducing air conditioning loads.

The development of spray-applied radiant barriers will provide roofing contractors with many more attractive options he can choose from.

For example, garage or warehouse doors, cathedral ceilings, overhangs where foil applications are not practical can now be provided with a radiant barrier that is easy to install and maintain.

Many contractors who had not used radiant barriers in the past are now using the spray-applied technology. In fact, the spray-applied radiant barrier has been proven so effective that it has recently been installed at the NAHB Research Center in the new *Lifestyle 2000 Home.*

In many commercial buildings, a foil radiant barrier system may be somewhat costly and difficult to install. In these applications, the spray-applied radiant barrier will provide a practical interior application. And because of the radiant barrier's high reflectivity, it will also act as a light reflector, possibly lowering interior lighting requirements and associated cooling loads.

Roofs that save energy

The benefits of using roof coatings have been well documented in recent

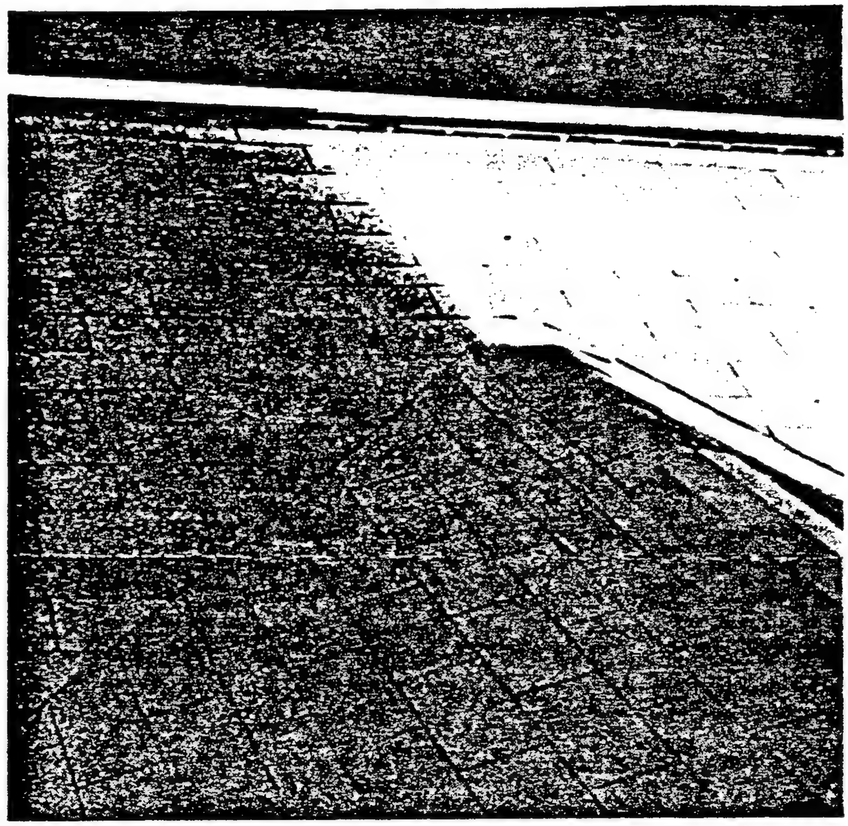
years. Now it is possible to have the protective benefits of a roof coating and the energy conservation benefits of a radiant barrier by using spray-applied radiant barriers, such as LO/MIT-1, on exterior roof surfaces.

Radiant barrier coatings are significantly different from many other roof coatings. Though most roof coatings are fairly reflective to sunlight, they are not always good reflectors of infrared radiation (the portion of the solar spectrum that creates most of the heat).

As an example, LO/MIT-1 has an emissivity of .24 on smooth roof surfaces such as metal, EPDM and other single-ply systems, according to the manufacturer, Solar Energy Corporation, Princeton, NJ.

This means that it reflects 76 percent of the incoming infrared radiation. Most standard roof coatings will reflect, at best, only 20 percent of the incoming infrared radiation. Visible light reflection for both the radiant barrier coatings and the standard roof coatings is generally 85 percent or higher.

Because of their low emissivity, radiant barriers coatings tend to keep roof surfaces up to 10 degrees cooler than standard roof coatings. In addition, they are unaffected by U.V. radiation, temperature-tolerant from −100° F to over 1000° F, and extremely flexible.



Energy consumption on residential structures can be cut as much as 10 percent when radiant barrier coatings are applied to composition shingle roofs.

Spray-applied interior radiant barrier is installed on the underside of the roof deck.

Using a radiant barrier coating will protect a roof surface from U.V. and greatly extend its longevity by reducing expansion and contraction. In the summer, thermal shock due to afternoon rain showers will be greatly reduced through the use of a radiant barrier roof coating. By lowering the ability of the roof surface to emit or radiate heat, the roof surfaces are generally cooler during the heating season. This means the building is subject to less heat loss and experiences reduced heating loads.

In areas of moderate to heavy snowfalls, snow will tend to stay on the roof surfaces coated with a radiant barrier longer. As long as outside ambient temperatures are below 32°F, snow acts as an excellent insulator, especially when it is light and fluffy, adding to the insulation value of the roof assembly.

Radiant barrier coatings are a low cost method of lowering air conditioning loads, increasing roof system longevity and possibly saving on heating costs. This new technology will expand the options of the roofing contractor when selecting a roof coating.

Residential opportunities

Radiant barrier roof coating systems can be used on practically all roof systems. As an example, in July, 1988, a single-family residence located in South Florida had a radiant barrier roof coating applied on a gray fiber-glass/asphalt shingle roof. The energy consumption and temperature data for the year prior to, and the year after the installation date was compared.

Even though the cooling degree days had increased 12 percent during the year when the radiant barrier roof coating was installed, the energy consumption or total usage decreased over 10 percent, proving how effectively radiant barrier roof coatings can conserve energy.

The Florida Energy Efficient Building Code and many utilities nationwide are promoting the use of radiant barrier systems in new construction and retrofit as a method to conserve energy. Reflective roof coating programs will see additional benefits when using radiant barrier coatings.

It is entirely possible that in the near future all new homes and commercial buildings will include some type of radiant barrier system as more contractors and consumers become aware of this inexpensive and practical method to reduce energy costs while improving interior comfort.

Now, spray-applied radiant barriers can offer the advantges of this unique technology both inside and outside of the structure. **RSI**

INSTANTANEOUS WATER HEATERS

VENDOR INFORMATION

Instantaneous Demand Water Heating We can't recommend instantaneous water heaters highly enough. Standard tank-type water heaters account for about 20% of all the energy we use in our homes. Many people keep their water heaters at 140°, wasting energy and shortening the tank's life. These energy-saving tankless heaters have been in use almost exclusively for years in Europe and Japan. In fact, America is one of the few civilized countries in the world backward enough to still use the archaic technology of storage tanks. They provide instant hot water when you need it, eliminating the need to heat 30 or more gallons in anticipation of your hot water demands.

Our favorite analogy that illustrates the stupidity of tank-type water heaters is the one about the car. Keeping 40 gallons of water hot at all times just in case you might need it is the same as leaving your car running in your garage 24 hours per day, seven days a week, just in case you decide you need to go for a drive! Doesn't it make more sense to heat the water only when you need.

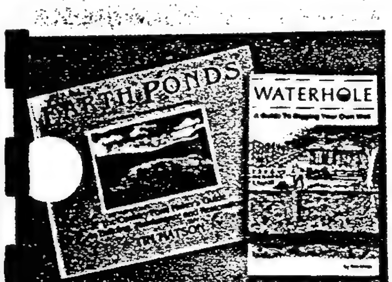
Paloma Tankless Water Heaters

The Paloma is regulated by restricting water flow to raise temperature. The Paloma PH-6 (43,800 btu/hr) is our best seller providing 1.4 gpm at a 50° F temperature rise, adequate for one tap. The PH-5 (1.2 gpm @ 50° temperature rise - 38,100 btu/hr) at less than 16" high installs easily into shower stalls or under counters. The Paloma PH-12 (89,300 btu/hr) will produce 2.9 gpm @ 50° rise. The Paloma carries a limited 5-year warranty on the heat exchanger and a 3-year warranty on other parts. Available in white only. Most of our customers want propane models. If you want Natural Gas (NG) you MUST order it that way!

45-201-P	PH5-LP	$279
■45-201-N	PH5-NG	$279
45-202-P	PH6-LP	$419
■45-202-N	PH6-NG	$419
■45-203-P	PH12-LP	$795
■45-203-N	PH12-NG	$795

All shipped w/draft hood except PH5

45-231	Draft hood for PH5	$ 55



Waterhole: A Guide to Digging Your Own Well, by Bob Mellin, who has hand-dug several wells using the technique he recommends. This small but thorough book deals with all aspects of one of the simplest of tasks: digging a hole in the ground: site selection, where not to dig, how to dig, how to keep the hole uncontaminated, digging and pumping equipment. This book treats only one type of well, the small-bore auger dug well, with humor and balance. Very much in the tradition of great RG do-it-yourself books. 72 pages. 80-614 $9

Earth Ponds, by Tim Matson. This is a thorough and attractive treatment of a small subject. The first edition of this book appeared a decade ago, and was instrumental in the sculpting of thousands of ponds around the world. This new edition is much larger, more professionally illustrated, but, most important, it has grown through the author's experience, a wealth of anecdote and research back to the 17th century, and attentive love for his subject. This book is utterly indispensable for all pond dreamers, builders and owners everywhere. 150 pages. 80-626 $17

Our Favorite Solar Water Heater

The phenomenal Copper Cricket, under ideal conditions, will provide 52 gallons per day of 160° water, enough for 3-4 people. And it's a passive system. Absolutely no controls, pumps or freeze protection required! The Cricket uses your existing electric or gas water heater, not an expensive "solar" storage tank. The remote flat plate collector can be as much as 36 feet above the tank. Complete system includes solar pad heat exchanger, valve pack with mounting and connnecting hardware. System life expectancy is over 30 years. Installation kit includes drain valves, hand vacuum pump, access valves and miscellaneous parts. We're leaving out reams of convincing technical detail; call us for more information and enthusiastic endorsements.

■45-405	Copper Cricket	$2,180
■45-417	Crating Charge	$50
■45-415	Installation Kit	$150

Shipped Freight Collect from Oregon
Allow 4 weeks for delivery

Instant Hot Water by Aquastar

Rated #1 by the leading consumer magazine, the French-made Aquastar 80 (77,500 btu/hr) is designed for use with one tap at a time and will produce 1.8 gallons per minute at a 60° temperature rise. The larger Aquastar 125 (125,000 btu/hr) will produce 3.25 gpm at a 60° temperature rise. The largest Aquastar 170 (165,000 btu/hr) is designed for huge houses, car washes, and fast food restaurants. Aquastar is the only tankless heater that can be used with preheated water systems. The "S" series is designed for solar or woodstove preheated water. All models feature a safety thermocouple at the burner and pilot, an overheat fuse, a manual burner control adjustment for finer temperature control, and built-in gas shut-off valves.

Aquastars have a 10-year warranty on the heat exchanger and a 2-year warranty on all other parts. Most of our customers want the propane models. If you want Natural Gas (NG) you *MUST* order it that way!

45-102-P	Aquastar 80LP	$545
45-102-N	Aquastar 80NG	$545
45-105-P	Aquastar 125LP	$625
45-105-N	Aquastar 125NG	$625
45-106-P	Aquastar 80LPS	$595
45-106-N	Aquastar 80NGS	$595
45-107-P	Aquastar 125LPS	$695
45-107-N	Aquastar 125NGS	$695
■45-104-P	Aquastar 170LP	$995
■45-104-N	Aquastar 170NG	$995

Model 170 *only* shipped freight collect from Vermont or L.A.

Copper Cricket

"The most exciting, cost-effective solar hot water system to be developed in the last decade." - Worldwatch Institute.

"It is what solar always should have been...it ought to replace pumped and controlled active systems...Personally I'd recommend it as the best system on the market." - Amory Lovins

DESIGN REVIEW OF A

SOLAR HOT WATER HEATING SYSTEM

FOR

BUILDING 43084

Sandia National Laboratories

Albuquerque, New Mexico 87185-5800

February 9, 1994

Department of the Army
U.S. Army Intelligence Center and
Attn: Bruce Johnson
Senior Mechanical Engineer
EPS Division, DEH
Fort Huachuca, Arizona 85613-6000

Dear Mr. Johnson:

This letter is in response to your request for Sandia National Laboratories to review a detailed design of a solar domestic water preheat system for Visitors Quarters Building No. 43084 at Ft. Huachuca, Arizona.

In early November of 1993, I measured the hot water load for Building No. 43084 and found it to be 850 gallons per day. Personnel at the billeting office report that this building has a high year round occupancy rate; therefore, the hot water load should be constant throughout the year. The attached spreadsheet gives a monthly breakdown of the expected natural gas savings and cost savings if the proposed solar system were to be installed. This solar system would provide approximately 60% of the yearly hot water energy needs.

Specific comments regarding the solar system design are:

1. I suggest the elimination of the 2", 3-way mixing control valve that mixes cold water with discharge hot water if the tank temperature is too high. This feature is unnecessary and its elimination would simplify the piping and controls, reduce installed cost, and reduce maintenance.

2. I suggest that a BTU monitoring system be incorporated into the design. A BTU system would allow base personnel to quantify the actual energy savings and aid in identifying when a problem exist with the solar system.

3. A common complaint from solar system suppliers is the specification of non-standard components which tend to increase the first cost of the system. For example, this design includes a very detailed description of the collector support rack, while a suppliers standard support system may perform the task and be significantly less expensive. A performance based contract would minimize this problem and allow the contractor to determine a cost-effective approach to satisfy the conditions specified.

The design is thorough and contains no flaws that would adversely affect its performance. I have attached the drawings and specifications that were loaned to me for review. If I can be of any further assistance, please do not hesitate to call.

Sincerely,

John Anderson, 6216
Solar Thermal Technology

Copy to w/o attachments:

Ft. Huachuca		B. Stein
6215	MS 1127	C. P. Cameron
6215	MS 1127	E. E. Rush
6216	MS 0703	C. E. Tyner
6216	MS 0703	D. F. Menicucci
6216	MS 0703	J. R. Anderson

JULY 1993

SOLAR THERMAL SITE SURVEY

LETTER REPORT

Sandia National Laboratories

Albuquerque, New Mexico 87185

July 23, 1993

Department of the Army
U.S. Army Intelligence Center and
Fort Huachuca
Directorate of Engineering and Housing
Attn: Bill Stein
Fort Huachuca, Arizona 85613-6000

Dear Bill:

Thank you for taking time out of your busy schedule to escort Earl and me around the Base. You have some interesting projects lined up and we look forward to working with you on the analysis. The following is a brief summary of the projects we discussed and the appropriate Sandia activities have been identified. Sandia will begin the identified activities after receiving notification from the Corps to proceed.

Greeson Pool:
This pool is only used for two and one-half months during the summer. A solar blanket is used during the night and all day Sunday and Monday when the pool is closed. No other pool heating is currently being used, that is, the pool is currently only heated by solar gain. We feel the short usage period and no current fuel cost will keep this project from showing an economic payback. If the decision is made to increase the operating period of the pool then a solar thermal system may satisfy the current ECIP economic criteria.

Visitor Quarters:
The visitor quarters consist of four structures with flat roofs that are used like hotels. Two of the buildings (43084 & 43085) have a domestic hot water storage tank that is charged with a gas-fired domestic hot water heater. A rough economic analysis will be performed using the existing storage tanks as solar charged preheat tanks. If the economic analysis is encouraging, the actual hot water load will be monitored to determine if the existing water heaters can supply the necessary energy during peak periods without solar assist, that is, without the storage tanks charged. If so, a detailed analysis will be performed. If this analysis meets your economic acceptability criteria, then a similar analysis will be applied to the NCO barracks and training barracks as they have similarly designed hot water systems.

If the analysis above meets the ECIP criteria, an analysis will be performed for the other two visitor quarters that will include storage vessels.

Visitor quarters building No. 43086 has a steam boiler that charges the domestic hot water storage tank. The steam lines and heat exchanger/storage tank were uninsulated. If insulation of these components is not scheduled, we suggest that it be considered as the payback on this type of energy conservation projects is generally quite short.

Ragatz Hall:
This is a one story administration building with a flat roof. The building is occupied five days a week from 7:00 a.m. until 5:00 p.m. The domestic hot water is supplied by a 52-gallon electric water heater and the hot water is recirculated. We feel that the hot water load is too small to justify the installation of a solar system. We recommend that a timer be used for the water heater and the recirc pump. A timer could reduce the pump energy usage by about 70% just by turning the pump off during non-working hours.

Yardley Cafeteria:
This building serves three meals a day and is closed every other weekend. It is a new building with a seamless metal roof. Installing collectors on this building would probably void the roof warranty, and, there is no available land area adjacent to this building. The lack of a location for the collectors makes this project potentially unattractive for a solar installation.

Barnes Field House:
This building has two existing solar systems. One system supplies domestic hot water and is fully functional. The other system provides pool heating. One sixth of this system is not in service and two of the panels are missing. An economic analysis will be done to show the payback on replacing the two panels. Meanwhile, we recommend that copper spool pieces be installed to allow the remaining portion of this section of the field to be placed back into service. One absorber plate is missing, and we recommended that the taps in the header piping for the associated receiver tube be capped. I also recommend that you investigate the use of a pool cover as pool covers often show a fairly quick payback.

JITC:
This building has a 100-gallon gas water heater and a recirc pump. The building is occupied seven days a week and, at times, 24 hours a day, and showers are used regularly. Monthly gas usage figures have been given to Sandia for this building; however, the usage figures are so high that a more thorough building system inspection will need to be performed to verify that the entire summer gas usage is for domestic water heating purposes only. Sandia will inspect the operation of the facility systems and meter the hot water load.

West and East Airfield Hangers:
Very little hot water load exists in these buildings. We suggested that energy conservation methods be researched such as the use of a timer on the recirc pumps or eliminate the recirc pumps. You might consider eliminating the recirc pump in the west hanger and installing a small electric water heater in the west part of that building as this is a long piping run which will have considerable heat loss when compared to the hot water usage in the west part of the building.

Old Firehouse:
This building has two flat plate collectors, heat exchanger, pump, controls and storage tank. It is believed that the controller is no longer functional. It is also believed that the new occupancy of this building will require very little hot water. This system will be evaluated for refurbishment and relocation to the JITC building.

Residential Domestic Hot Water Systems:
There are approximately 1950 residential quarters on base and the orientation of the buildings varies considerably. Approximately one half of the buildings have flat roofs and one half have pitched roofs. The pitch varies from 1 in 12 to 3 in 12. Approximately one half of each style of housing has the water heater located external to the building and the other half located central to the residence. It is reported that many (150 to 500) domestic water heaters are replaced yearly due to the hardness of the water. A solar preheat system would extend the life of the water heaters. We will evaluate the economics of using solar water heaters for a number of these residences incorporating the expected life increase of the conventional water heaters.

Converting Slump Block Wall to Trombe Wall:
The short heating season at Fort Huachuca would keep this expensive retrofit from being cost effective. In addition, most of the slump block structures are relatively new and attractive buildings. Converting these to trombe walls would require the installation of glazing and exterior insulation. The exterior would then need to have a stucco type finish applied which would change the appearance of the buildings. We feel this project would have an extremely long payback and is not a candidate for further study.

Other items that Sandia will investigate:

1. The use of Lo-Mit 1 roof coating. This passive solar coating has potential for reducing building cooling loads and investigation will be performed to determine the best applications for the coating at Ft. Huachuca.
2. The compatibility of residential instantaneous water heaters with solar preheat. Ft. Huachuca is interested in investigating the use of instantaneous hot water heaters in a residential application. There is a concern that some, perhaps most, instantaneous heaters are designed for cold water inlet only, hence, not compatible with a solar hot water preheat system.

Per your direction, we will use the following energy prices for all analysis:

Natural Gas, both residential and Army use - 50 cents a therm ($5.00 per MMBTU)

Electric:
- Demand charge - $11.30 per kW
- May through Oct - 4.6935 cents per kWH + 2.3 cents per kWH (for distribution O&M)
- Nov through April - 4.4588 cents per kWH + 2.3 cents per kWH

We suggest that you survey your buildings and consider the use of timers on recirc pumps and electric water heaters where appropriate. We also suggest that you consider lowering the domestic hot water temperature setpoint where appropriate. These energy conservation ideas will save energy and should provide quick paybacks.

Sincerely,

John Anderson
Solar Thermal Technology
Department 6216

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